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RESEARCH NEEDS TO REDUCE MARITIME COLLISIONS, RAMMINGS, AND GRO--ETC(U)
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RESEARCH NEEDS TO REDUCE MARITIME COLLISIONS, RAMMINGS, AND GROUNDINGS

Maritime Transportation Research Board

Committee on Research Needs to Reduce Maritime Collisions, Rammings, and Groundings

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

Public concern about the consequences of serious marine accidents is increasing. Collisions, rammings, and groundings as a group are the accidents most often associated with significant loss of lives and property and harm to the environment. The public is demanding that industry and government act to reduce the numbers and effects of such casualties. This report identifies long-range research and development efforts designed to do so.

As documented in the report, numerous maritime research and development efforts have produced results that bear on the reduction of collisions, rammings, and groundings. This research is largely uncoordinated, however, and gaps and overlaps occur. Further, little has been achieved in bringing to the maritime field the results of research in other areas, such as aerospace. It is apparent that valuable lessons may be learned by drawing on experiences in nonmaritime fields.

The committee that prepared this report included members experienced in ocean shipping, inland waterway transport, and offshore support operations, as well as representatives from a variety of related fields. Early in its deliberations, the committee concluded that each of these three segments of the industry had unique problems relating to the prevention of collisions, rammings, and groundings. To identify and categorize these problems as a guide for research, the committee employed a systems approach using functional-flow block diagrams to record each step in several typical vessel-movement sequences. These steps were then analyzed to determine what might conveivably go wrong at each point along the way. So far as the committee is aware, studies of vessel operations and step-by-step evaluations of causal factors have not previously been undertaken in just this way. It is hoped that the effort will provide continuing educational value.

The report stresses the presence in most marine casualties of one underlying cause: human failure. This very difficult area of needed research is critical to all transport activity, and experts in all modes of transport should join in a mutual attack on the problem. As the report indicates, technological research offers reasonable expectation of converting elements of the art of good seamanship into their equivalent technical performance.

Constraints on time prevented the committee from exploring aspects of collisions, rammings, and groundings that are not directly related to technological research but that may be important in reducing maritime casualties. These include management factors, economic pressures, professional competence, timeliness in implementing technological improvements, the Coast Guard budget, replacement of archaic port facilities, and the potential of aerospace developments.

The committee recognized the international implications of its task by relying on the international experience of several of its members as well as by examining pertinent literature.

The committee extends special thanks and recognition to Thomas A. Allegretti of the Transportation Institute and R.T. Dreghorn of Mystech Associates for their work with the committee. The committee also wishes to acknowledge the assistance of its Project Manager, Everett P. Lunsford, Jr., in organizing and coordinating its efforts and the editorial ability displayed by Linda Jenstrom and Kenneth Reese in pruning and polishing the text of its report.

Jerome Lederer

Jerome Lederer
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Needs to Reduce Maritime Collisions,
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EXECUTIVE SUMMARY

Society is demanding an ever higher level of safety from the marine industry in order to reduce pollution and otherwise safeguard the marine environment. As a result, standards and regulations for equipment and personnel are becoming more stringent. The current maritime safety record, as well as the attainable level of safety, are intluenced by industry traditions, environmental variables, and the political process. World political events and the changing U.S. economic position are prompting rapid changes in these areas, and such changes influence U.S. maritime policy and safety.

The mandate to this committee was to evaluate research needed to prevent marine casualties--specifically collisions, rammings, and groundings--associated with vessel controllability. A review of existing studies and casualty data, combined with the committee's experience, resulted in the identification of four major categories of marine-casualty factors: personnel; ports and waterways; aids to navigation; and vessel characteristics, maneuverability, and hydrodynamics. A significant amount of research on systems, hardware, and human behavior exists that is applicable to these categories. However, there are important gaps in basic hydrodynamic research. In addition, industry awareness of the available research information is limited, particularly at the operational level. Although human behavior is found to contribute to most maritime accidents, the industry is just beginning to examine the behavioral research applicable to the optimization of man-machine interfaces.

To organize accident causal factors systematically, the committee developed functional-flow block diagrams of events on a vessel's bridge, as described in Chapter IV. Problems or actions that could lead to a casualty were listed for each function on the diagram. Analysis of the diagrams showed that the majority of the problems identified could be described as failure to take correct action. The committee set out to match existing research reports and projects with the lists of problems, but quickly found the financial and time constraints prohibitive. At that point, the committee elected to focus on human-factors research. Chapter V outlines behavioral research applicable to reducing human error and explains how to gain access to the results of that research.

In contrast to the aerospace industry, the maritime industry conducts relatively little internal exchange of information. In addition, its members are generally unaware of potentially useful

research outside the industry, although extensive aerospace technology-transfer programs exist. In commercial air transport, extensive information on accidents and near accidents is widely distributed; this includes both the results of investigations and anonymous reports of errors and near misses. The committee determined that a basic problem in the maritime industry is not so much the lack of research, but a need to disseminate information, coupled with coordination of research and a serious effort to apply existing knowledge.

Conclusions

The committee reached the following conclusions on collisions, rammings, and groundings.

1. The causes of maritime casualties are seldom technologically sophisticated or obscure. Almost without exception, the *proximate or* probable causes of collisions, rammings, and groundings are well known and widely recognized as some form of human failing. Yet there is little recognition or understanding of the underlying causes of human error. Often casualties result from ignorance or disregard of common industry knowledge. Frequently, required or established operating procedures and/or maintenance and inspection criteria are overlooked or overruled. Why humans disregard, overlook, overrule, or ignore procedures is not sufficiently well understood.

2. There is an inverse relationship between the known causes of maritime accidents and the areas in which research is conducted. Most major marine casualties are due to some form of human failing, whereas most maritime research resources are expended on hardware.

3. In the opinion of many committee members and of experts who met with the committee, considerable maritime research results, for many reasons, are not implemented operationally.

4. The results of most research, not just maritime research, are published with little or no thought to "embedding" methodology--that is, arrangements for obtaining acceptance of the technological content and incorporating it into an operating system. Therefore, the technological content, however excellent, wastes away for lack of means of putting it to use.

5. Changes in vessel characteristics and in shipping patterns are beginning to press the state of the art in vessel control technologies, such as hydrodynamics and communications. In the future, more advanced knowledge in those areas will be

needed for the development of control systems and other hardware to help prevent collisions, rammings, and groundings.

6. There are diverse maritime data bases, but no comprehensive marine-safety data base and no centralized method of reviewing the safety material in the various data bases.

7. The U.S maritime industry is diverse. It includes oceangoing ships, inland-waterway and Great Lakes operations, and offshore exploration and development. Each segment serves different needs and sectors of the economy; therefore standardized, national measures and policies that do not recognize this diversity will not produce the intended results.

Recommendations

The foregoing conclusions led the committee to make the following recommendations to the Coast Guard, the Maritime Administration, and other interested public and private organizations.

1. Continuation and augmentation of the systematic methodology for determining causal factors established by the committee (Chapter IV) should be promoted to assure that maritime casualty research becomes balanced, holistic, and complete. The functional-flow diagrams comprise a valuable foundation upon which to integrate such research.

2. Additional research should be funded to determine why the known causes of collisions, rammings, and groundings are ignored or overlooked and why operating rules and procedures are not strictly adhered to at all times.

3. Research resources should be expanded for finding the root causes of human error in maritime casualties.

4. Additional research directed toward establishing industry guidelines for layout and display and control equipment for bridges and engine rooms should be funded. These standards must provide for improved man-machine interfaces for vessel control.

5. Research on reducing maritime casualties should be encouraged to address both the technological content and the "embedding" methodology, i.e., the arrangements for obtaining acceptance of the technological content and incorporating it into an operating system.

6. Available technology to reduce human-factor causes of collisions, rammings, and groundings should be adopted, and

research in the component technologies such as hydrodynamics, control systems, and communications should be funded.

7. An organization should be established to collect and maintain a data base on research applicable to marine safety and to maintain links with similar national and international data bases. This organization also should be responsible for disseminating research information affecting marine safety.

8. A committee should be established under the aegis of the Coast Guard to coordinate and review requirements and funds for research on reducing collisions, rammings, and groundings. The interagency Ship Structures Committee could serve as an organizational model.

9. A non-adversarial organization, similar to the Flight Safety Foundation and the NASA-FAA Aviation Safety Reporting System, should be established to collect and disseminate information on casualties, near-accidents, and operating practices.

10. A study of existing maritime laws and regulations should be conducted to determine if they are applicable and enforceable with respect to the total U.S. maritime environment. Results of this research would be used as the basis for recommendations for repeal or revision of obsolete or inappropriate laws and regulations.

CHAPTER I

INTRODUCTION

As the Committee on Research Needs to Reduce Collisions, Rammings, and Groundings conducted its investigation, much of the introduction to its report was being written by events at sea and on the inland waterways. During 1979, 799,688 gross tons of shipping (vessels over 500 gt) were lost to collisions, rammings, and groundings. The loss was nearly twice the average annual loss from such causes during the 5 preceding years, according to the 1979 report of the Liverpool Underwriters Association. Four examples follow:

- In the early morning of November 1, 1979, the freighter MIMOSA, outbound in ballast from Houston, collided with the tanker BURMAH AGATE, inbound with a cargo of 390,000 barrels of crude oil, in the anchorage area at the approach to the Houston Ship Channel. Both vessels were engulfed in flames as the tanker's hull was breached and her cargo set on fire. Following initial contact, the MIMOSA, ablaze and abandoned by her crew with engines running and rudder jammed over, was left to circle aimlessly amid oil-drilling platforms in the area. Several hours elapsed before she could be chased down, brought under control, and her fires extinguished. Initial fires on the BURMAH AGATE spread as a series of explosions began on the ship. Despite firefighting efforts, recurring explosions and ensuing outbreaks of fire plagued the vessel. As her hull was further torn by blasts, she settled to the bottom, but the fires did not burn themselves out until January 7, 1980, more than 2 months later! The loss of the tanker and cargo and the threat of pollution to Gulf shores were overshadowed by the deaths of 32 tankermen.

  A footnote to this tragedy is that on April 2, 1980, not quite 3 months after the BURMAH AGATE fire had finally died down, another collision occurred in the vicinity. It involved the freighter MASON LYKES and the tanker AMOCO CREMONA. This time, however, the tanker was outbound and light, and the fires aboard both vessels could be brought under control. Serious property damage resulted, but, fortunately, without accompanying loss of life.

- On July 19, 1979, 10 miles northeast of Tobago, the 210,257 dwt tanker AEGEAN CAPTAIN and the 292,666 dwt tanker ATLANTIC EMPRESS collided during heavy rain squalls and erupted in flame as oil poured from torn cargo tanks. Twenty-six crewmen of the ATLANTIC EMPRESS died. Both vessels were heavily damaged.

  Following separation, the fires on the AEGEAN CAPTAIN were extinguished, but not until 3 weeks later, when there was no longer any danger of pollution, did the harbor authorities of Curacao allow the crippled VLCC (very large crude carrier) into port. Meanwhile, explosions aboard the ATLANTIC EMPRESS prevented control of her fires. She was towed to sea. In spite of the efforts of her crew and salvors, there were new outbreaks of fire and continuing explosions. Eventually, water entered her ruptured hull. On August 2, some 350 miles from the collision site, the ship developed a severe list and sank.

  Losses and damages to the two tankers exceeded $52 million. The value of the approximately 300,000 tons of crude oil lost exceeded $55 million. The loss of 26 lives and indirect losses cannot be quantified.

- On October 20, 1978, at the mouth of the Potomac River in Chesapeake Bay, the U.S. Coast Guard Cutter CUYAHOGA and the freighter M/V SANTA CRUZ II collided. Neither vessel had plotted the other's course and speed, and neither had communicated with the other, although both had working radio equipment.

  In the confusion of identification and late maneuvering, the CUYAHOGA was struck and sank within 2 minutes. The monetary loss and pollution damage were minor, but 11 crewmen from the CUYAHOGA died.

- While maneuvering in Los Angeles Harbor on January 15, 1978, a U.S. tanker, the SEALIFT CHINA SEA, rammed a docked cargo ship, the LORENZO D'AMICO. The automated engine-control system on the SEALIFT CHINA SEA had failed as it had several times in the past. A jury-rigged control system, employing hand signals among engine-room personnel, was being used. An astern order was misinterpreted as an ahead order. The two tugboats on the bow could not counteract the resulting forward thrust, and the SEALIFT CHINA SEA rammed the LORENZO D'AMICO. Fortunately, no injuries resulted, and damage to the SEALIFT CHINA SEA and the dock was minor. The LORENZO D'AMICO, an older vessel, was declared a total loss.

The U.S. Coast Guard's statistical summary of casualties for 1978 records 2,555 collisions, rammings, and groundings reported for

vessels of all sizes. These accidents involved 5,021 vessels and resulted in 32 deaths and 53 injuries. Of the vessels involved, 628 were longer than 500 feet. The Coast Guard's estimate of direct loss and damage to vessels, cargo, and other property was $120 million.

Physical damages, of course, are the most readily calculable economic losses. However, other tangible and intangible losses inevitably result, and their collective impact may well be more severe. From 1974 to 1978, 5,800 commercial oceangoing and Great Lakes vessels were surveyed on behalf of U.S. underwriters by the United States Salvage Association, Inc. Total repair costs from 3,655 collisions, rammings, and groundings during those years were reported to exceed $450 million. The average repair cost exceeded $123,000, and the average repair time per casualty was 10 days. Estimates of the indirect costs to vessel owners and to those relying on the regular operation of these vessels are not available. In most cases, however, indirect costs probably exceed direct losses.

Background

The Maritime Transportation Research Board (MTRB) has long been concerned with the impact of marine casualties on the financial vitality of the industry, the health and safety of maritime personnel, the residents of shore-side communities, and the environment. The general subject of merchant marine safety was addressed by an MTRB committee in a 1970 study, Merchant Marine Safety.[1] (Superscript numbers refer to publications listed in the references following Chapter VII). A systematized program for collecting maritime-casualty data was proposed by another committee in 1973.[2] In 1976, human error as a factor in merchant marine safety was studied in an attempt to determine its underlying causes.[3]

With each passing year, the problems generated by maritime casualties grow more acute, and the economic, political, and social pressures for minimizing their number and severity grow stronger. Ship owners and operators are being pressed to find solutions to avoid adverse public reaction, and maritime casualties raise the specter of financial ruin for many. As a result, extensive research on the subject has been, and is being, undertaken in the United States and in other maritime nations. Studies have been initiated by industry, government, and academic institutions for a variety of reasons, including human safety, pollution control, and cost containment. Unfortunately, individual projects are undertaken for specific, prescribed purposes, and there is no comprehensive plan for coordinating maritime research.

Lack of a coordinated approach has left many unanswered questions. What research is under way? How good is it? How can the results of past and current research be obtained? To what extent have research findings been implemented and found effective? What research

remains to be done? How can it be coordinated? These questions were presented to MTRB by the U.S. Coast Guard (USCG). The request, in essence: evaluate the research needed to prevent collisions, rammings, and groundings.

Committee Organization

To carry out its mandate, MTRB formed a committee representative of all segments of the maritime community. People familiar with the practical aspects of ocean shipping, river transport, and offshore operations were invited to participate. Representatives from marine underwriters and government regulatory agencies were included and asked to supply data relevant to the causes of marine casualties. An industrial psychologist and union personnel provided insight into the human-behavior component of marine casualties. A hydrodynamicist was asked to join the group to ensure that problems of vessel control and maneuverability problems would be properly addressed. A system-safety analyst was included so that the study could be organized in comprehensive, cohesive fashion. Finally, in recognition of the advanced state of aviation safety and the lessons that it might teach, a specialist in that field was asked to bring his experience to bear on maritime problems. With this broad base of expertise, the Committee on Research Needs to Reduce Collisions, Rammings, and Groundings began its deliberations.

Project Scope and Objectives

At the outset, the committee focused on two designated areas of interest: ship hydrodynamics and the influence of ship bridge design and equipment on vessel control. The committee was quite prepared to concentrate on vessel-control factors related to collisions, rammings, and groundings. Such casualties are distinct from fires, explosions, and other traditional "perils of the sea" in which vessel control is not directly related to the event.

Early in its deliberations, however, the committee concluded that emphasis solely on hydrodynamics, bridge design, and other technical aspects would be too confining. Many factors, and complex interrelationships of factors, were seen as contributing to maritime casualties involving vessel-control problems. Therefore, without deemphasizing any single aspect, the committee concluded that it should extend its inquiry to all factors that might bear on control-related maritime casualties. The committee also determined that its work should encompass not only oceangoing vessels, but also coastal and harbor craft, vessels operating on the rivers and the Great Lakes, and those operating in support of offshore industrial development.

The committee then established the following objectives:

- To identify factors that influence maritime collisions, rammings, and groundings;

- To assess current research applicable to the factors identified above;

- To identify additional research required for reducing collisions, rammings, and groundings; and

- To propose a method for organizing and conducting maritime research applicable to reducing collisions, rammings, and groundings.

Definitions of research typically do not incorporate time limits. In working toward the foregoing objectives, however, the committee felt that it had to adopt time restrictions in recognition of the immediacy and severity of the problem. Therefore, the committee decided to concentrate on what might be accomplished through research during the 20 years 1981 through 2000. In other words, the committee set out to define what research might accomplish for the current and next immediate generation of ships.

A second and equally important problem is that the findings of a vast amount of research both inside and outside the industry have generally been ignored. Indeed, most of the industry appears to be unaware that such findings exist. Therefore, the committee felt that it should determine why research findings rarely are implemented. Conclusive proof for the cause of low implementation of research results is difficult to obtain. However, the committee proposed a number of causative factors:

1. Researchers are not rewarded for having their conclusions implemented. Their reward is publication of their findings.

2. Specialization due to complexity often forces researchers to focus exclusively on proving feasibility of a concept and to leave its implementation to someone else.

3. Everyone resists change in status quo, and those with lengthy historical roots--e.g., the maritime industry--tend to accept few new concepts.

4. The maritime industry is concerned about potential litigation by all parties affected by implemented research findings.

5. Research reports are not written for widespread reading. Academic writing style often masks the practicality necessary for adoption of research findings.

6. Research is often viewed by researchers as an end in itself, rather than as a means to solving a problem. Research

reports frequently are designed to prescribe follow-on research instead of focusing on a terminal result capable of implementation.

7. The general public has been conditioned to view research as providing "guaranteed answers," thus bringing pressure on researchers to avoid obtuse problems--e.g., those with a large human behavioral component--and to focus on problems that will readily yield discrete, technological solutions that should not require as much implementation effort.

8. The economic requirement to assure cost-effectiveness of implemented research is often overlooked in the research process. This results in almost automatic rejection by cost-conscious managers who must implement research findings.

Having defined its tasks, the committee began to develop background information. Chapter II presents the committee's assessment of the current maritime environment, the factors stimulating change within the industry, and the impact of these factors on the directions of maritime research. Chapter III outlines causal factors and their interrelationships considered influential in collisions, rammings, and groundings.

The committee felt it imperative that one or more methods be developed to clarify the roles of these causal factors and elucidate the areas in which more research is needed. Accordingly, a method based on the development and analysis of functional-flow block diagrams was designed and implemented (see Chapter IV).

The committee also sought to identify available research applicable to vessel control. As work on the functional-flow block diagrams proceeded, it became apparent that the list of potential failings of either men or machines was dominated by a single class of human behavior: "failure to perform (a task) satisfactorily." Therefore, the committee directed its attention to the behavioral-science literature dealing with accidents and human error. There is a significant body of such research, but committee members soon realized that there were so many causes of human error that the only practical course was to develop a bibliography and an overview of the major areas of potentially promising maritime research (see Chapter V).

The collection and exchange of casualty information is covered by Chapter VI. Chapter VII presents the rationale behind the conclusions and recommendations reached by the committee.

CHAPTER II

CURRENT MARITIME ENVIRONMENT

This analysis of the research needed to reduce maritime collisions, rammings, and groundings begins with an assessment of the current environment of the industry. That environment depends on two major elements: the national and international organizations that carry out functions related to ship safety, and the factors most critical to the changing character of the industry. Both elements are discussed in this chapter.

Organizations That Affect the Maritime Environment

Many public and private agencies, organizations, and groups are involved in various aspects of waterway transportation (Table 1). Most of them are concerned in part with matters related to the prevention of collisions, rammings, and groundings, but the public holds the government organizations responsible for ensuring marine safety. The federal agencies with responsibilities for marine safety are the U.S. Coast Guard, the Federal Communications Commission, the Maritime Administration, the Army Corps of Engineers, and the National Transportation Safety Board. Classification societies, such as the American Bureau of Shipping, also play a key role because certain safety functions have been delegated to them by the government. Internationally, the Intergovernmental Maritime Consultative Organization (IMCO) is the principal organization that deals with marine safety.

Each of the organizations mentioned above influences the safety of a ship at various times during its life, beginning at the drawing board and ending in the scrap yard. Table 2 shows the major organizations and their areas of regulatory responsibility.

Changing Character of the Industry

The maritime industry, like any other, is under continuous pressure to change by forces both external and internal. These forces are countered by economic, technological, and social inertia. Thus, in the short run, the resultant changes may seem insignificant.

TABLE 1 Representative Agencies and Groups Concerned with Various Aspects of the Waterway Transportation System

Vessel Inherent Maneuverability (Hull, Propulsion, Steering)

Society of Naval Architects and Marine Engineers
Coast Guard
Maritime Administration
IMCO Design and Equipment Subcommittee
American Bureau of Shipping
National Transportation Safety Board
Oil Companies International Marine Forum
American Institute of Merchant Shipping
International Towing Tank Conference
Corps of Engineers Waterways Experiment Station
Vessel Owners and Operators
American Waterways Operators
Council of American Flag Ship Operators

Vessel Control (Human Controller, Control Information, Control Informat'on Sources)

Coast Guard
Maritime Administration
Vessel Owners and Operators
Maritime Labor Organizations
IMCO Safety of Navigation Subcommittee
Merchant Marine Academies and Schools
National Oceanic and Atmospheric Agency (charts)
NAS/Maritime Transportation Research Board
National Transportation Safety Board
Oil Companies International Marine Forum
American Institute of Merchant Shipping
Federal Communications Commission (radio and radar)
Pilots' Organizations
Merchant Mariner's Organizations
Institute of Navigation

Environmental Conditions

National Oceanic and Atmospheric Administration (weather)
Corps of Engineers (current in river system)

Traffic

Coast Guard
IMCO

Configuration of Waterway

Corps of Engineers
Permanent International Association of Navigation Congresses
International Association of Ports and Harbors
American Association of Port Authorities

Aids to Navigation

Coast Guard
International Association of Lighthouse Authorities

Operating Rules

Coast Guard
Corps of Engineers
IMCO
State and Local Authorities
Maritime Labor Organization

Tugs

Coast Guard
Docking Pilot's Association
Tugboat Companies

TABLE 2 Maritime Organizations and Regulatory Responsibilities

	DESIGN AND CONSTRUCTION	MANNING	NORMAL OPERATION	INSPECTION AND REPAIR	ACCIDENTS
U.S. COAST GUARD	SETS STANDARDS THROUGH REGULATION REVIEWS PLANS INSPECTS DURING CONSTRUCTION	LICENSES OFFICERS QUALIFIES SEAMEN ENFORCES U.S. MANNING LAWS	MANAGES VISUAL AND RADIO AIDS TO NAVIGATION, REGULATES TRAFFIC, ENFORCES U.S. MARITIME LAW	CONDUCTS PERIODIC INSPECTIONS OF U.S. VESSELS AND CERTAIN TYPES OF FOREIGN VESSELS, INSPECTS DAMAGE AND REPAIRS	INVESTIGATES ACCIDENT TO DETERMINE CAUSE ANALYZES SYSTEM FAILURES INITIATES ACTION TO REMEDY FAILURE
FEDERAL COMMUNICATIONS COMMISSION	REQUIREMENTS FOR RADIO INSTALLATIONS	LICENSES RADIO OPERATORS	RULES FOR RADIO OPERATION	INSPECTS RADIO OPERATION	N/A
MARITIME ADMINISTRATION	REQUIREMENTS FOR SUBSIDIZED SHIPS INSPECTS SUBSIDIZED SHIPS DURING CONSTRUCTION	N/A	N/A	N/A	N/A
ARMY CORPS OF ENGINEERS	N/A	N/A	SETS OPERATING RULES FOR LOCKS, DAMS, AND WHARFING	N/A	N/A
NATIONAL TRANSPORTATION SAFETY BOARD	N/A	N/A	N/A	N/A	INVESTIGATES CERTAIN ACCIDENTS RECOMMENDS ACTION TO COAST GUARD AND OTHERS
INTERGOVERNMENTAL MARITIME CONSULTATIVE ORGANIZATION	INTERNATIONAL STANDARDS FOR VESSEL CONSTRUCTION, INSPECTION, AND EQUIPMENT	INTERNATIONAL STANDARDS FOR MANNING SCALES, AND TRAINING AND WATCHKEEPING	ESTABLISHES VESSEL TRAFFIC SEPARATION SCHEMES	EQUIPMENT INSPECTIONS REQUIRED BY SAFETY OF LIFE AT SEA (SOLAS) CONVENTION	N/A
CLASSIFICATION SOCIETIES	PUBLISHES DESIGN STANDARDS INSPECTS VESSELS DURING CONSTRUCTION	N/A	N/A	REQUIRES PERIODIC INSPECTIONS INSPECTS DAMAGE AND REPAIRS	N/A

In seeking those parameters that influence the need for further research regarding maritime collisions, rammings, and groundings, it is necessary, first, to identify the forces that are changing the character of the industry and, second, to assess the impact of such changes on future research. The following group of forces for change is illustrative rather than exhaustive. Further, the factors listed are not equal in importance or effectiveness and are not discussed in order of consequence.

New Ocean Uses: Throughout history, the oceans have been viewed as a transportation medium. Certainly, the fishing fleets plied the seas as a source of food and income, but the importance of the oceans for transportation was primary. In recent years, however, the seas have become increasingly important as sources of oil and minerals. Thus, the maritime industry must now accommodate unfamiliar fixed and mobile facilities, different types of ships, new cargo combinations, and increased international competition.

Shift of Influence: The influence of the traditional western maritime nations, in terms of tonnage and other factors, has shifted recently to the developing nations. This shift is providing the impetus for establishing many new international regulations in areas previously controlled by sovereign policy makers.

U.S. Position: At the end of World War II, the United States was the dominant maritime power and so had a strong voice in international maritime law as well as an important influence on ship design and marine operations. That paramount position has gradually eroded. Today, both internationally and domestically, the U.S. maritime industry no longer plays its former authoritative role.

Management Philosophy: The traditional management philosophy in many industries is to react to crises rather than to plan to avoid them. The impetus for changing this tradition has been weaker in the maritime industry than in many others. Thus, the U.S. maritime establishment still exhibits a predominantly crisis-oriented approach to decision-making, which will continue to reduce the nation's leverage in the international marketplace.

Personnel Expectations: Recent years have seen growing interest in assessing the role of the U.S. seaman as well as his perception of himself and his seagoing career. The romance of the seafaring life is no longer a significant attraction. The increasing social and technological sophistication of U.S. society has changed the life of the seaman at least as rapidly as it has altered life ashore. The seafaring career continues to attract young men, albeit for different reasons than a generation ago, but very few stay in the industry. Both maritime labor leaders and management recognize that a stable, competent work force is important to the industry's viability and growth. If the industry is to retain a qualified work force, it must continue to move toward a better understanding of the seaman, his

vessel and shoreside environments, and the factors affecting his career.

Public Involvement: There is a growing public appetite for information formerly considered either proprietary or to be withheld pending an established need to know. This appetite has created an environment that is bound to change the maritime industry. For example, sunshine laws and freedom-of-information legislation have altered management decision-making. Once the public becomes knowledgeable about an issue, the climate of public opinion makes additional demands on management. This phenomenon does not seem likely to abate in the near future.

Traditions of the Sea: From ancient times, a ship's captain has been an authority unto himself. His autonomy was unquestioned. Today, that traditional autonomy is evaporating rapidly, and maritime activities increasingly are viewed as an adjunct of a land-based corporation or multinational conglomerate.

Public Risk: Economic pressures have dictated increasing length and tonnage for cargo vessels. In addition, the diversity of cargoes, especially in terms of toxicity and explosivity, continues to expand. Thus, the exposure of the general public to ever-higher risk appears inevitable, particularly in populated port areas.

Energy Requirements: The high cost of energy in the United States and the high ratio of energy consumed to that produced domestically have caused an intensifying focus on the maritime industry as the carrier of imported petroleum products. This pressure forces modification of management policies, labor relations, operating schedules, and resource allocation.

Art-to-Science: The folklore and traditions of the sea form a strong bastion against the adoption of scientific methods in the maritime industry. While many operational elements may continue to be an art, there is a great need to adopt the scientific approach in areas like ship instrumentation and control, rules of the road, and maritime communications. The need becomes particularly critical as maritime operations come under international regulation.

Maritime Education: Maritime technology is now recognized as a respectable and challenging field of study in several major universities. It is anticipated that there will be a continuing shift away from antiquated practices, passed on by generations of seafarers, and toward a more technological approach to maritime operations. Curricula that cover not only hydrodynamics and ship design, but also personnel relations, communications, handling of hazardous cargoes, port-facility operations, and the "embedding" of technology are bound to change many fundamentals of future maritime operations.

Marine Technology: In the maritime industry, as in most others, there is generally a time lag between the development of technologies and their implementation. Technology now available to the maritime industry potentially could reduce collisions, rammings, and groundings, but it has not been universally incorporated into maritime operations. Barriers to the adoption of new technologies are many and varied; they include simple resistance to change, the highly technical nature of research reports, and assessments of cost-effectiveness. Nevertheless, technology, though often belatedly implemented, will continue to change all areas of the maritime world.

Specialized vs. Standard Vessels: Since the generation of standard-design vessels built to fill the transport needs of World War II, the trend has been toward specialized vessels built to carry particular cargoes in a variety of trades. The benefits of specialization are many, but unique problems arise in selecting, training, and maintaining crews capable of operating special vessels. It is more difficult to make crews interchangeable, and the dangers of working on unfamiliar vessels are compounded.

Role of the Coast Guard: The mission of the U.S. Coast Guard is constantly being enlarged. Generally, such enlargement is not accompanied by increased resources. This obvious dilution of effort forces revision of priorities. The routine enforcement of rules and regulations often must be supplanted by more dramatic responsibilities. When this occurs, the potential for accidents is increased.

Ecological Impact: Spectacular oil spills in recent years around the world have alerted the public to the hazard that maritime accidents pose to the environment. Ecologists and conservation interests are a major deterrent to expansion of maritime traffic.

Casualty Visibility: The desirability of coastal areas as vacation, recreation, or residence sites is attracting growing populations to them worldwide. As a result, shore areas can become grandstands from which many people may observe the effects of maritime casualties. Those attracted to coastal areas often are the more affluent members of society and are likely to be vocal about the deleterious effects of such accidents.

Remote Port Facilities: More and more off-loading facilities are being planned for sites some distance offshore rather than within a port facility surrounded by a population center. This change has created new environmental and safety concerns at the same time that it supposedly reduces hazards. Navigation, communications, and berthing at such facilities present a new set of problems, albeit less serious in many cases than those in traditional port facilities.

Accident Losses: The dollar loss from any maritime accident is estimated more accurately today than in the past. Many factors

previously combined as "indirect losses" are now costed out separately. Since loss estimates have become more accurate, maritime managers are better able to measure the cost-effectiveness of specific accident-prevention measures and can allocate resources more efficiently.

News Media Influence: Like other components of society, the maritime industry is vulnerable to the influence of the press. The news media's ability to mobilize public opinion for or against any industry, including the maritime industry, should not be underestimated. To avoid misrepresentation in the press, the maritime industry should take steps to overcome technical ignorance, oversimplification, or bias.

The many factors affecting the status of the maritime industry, as well as the increasing numbers and complexity of regulatory interactions, will influence the direction and effectiveness of maritime research. It is critical, then, that those engaged in making policy, allocating research funds, or exploring the potential of new scientific concepts be aware of and responsive to the character of the environment within which the industry operates.

CHAPTER III

CASUALTY CAUSAL FACTORS

Successful shiphandling depends on three separate functions: acquiring the right information; making the right decisions; and performing the right maneuvers. Although these functions are simply stated, examination of shiphandling soon reveals its complex nature. For example, it is influenced by many factors, including the ability of the person controlling the ship, the adequacy of the information received, the responsiveness (inherent maneuverability) of the vessel, the characteristics of the waterway, and the state of the environment. The factors influencing shiphandling are shown in organized form in Figure 1.

The waterway system, like its counterpart, the highway system, works well most of the time, and ships deliver their cargoes without incident. Sometimes, however, an accident occurs. In most cases, how or why the system did not work as planned is easily understood. Still, the complexity of the human failings in many cases makes it difficult to identify and correct weaknesses in the system.

To bring some order to the discussion of causal factors in marine casualties, the committee divided the elements of the waterway transportation system into four rather arbitrary groupings: personnel; ports and waterways; aids to navigation; and vessel characteristics, maneuverability, and hydrodynamics. Factors that may contribute to collisions, rammings, and groundings are discussed below in terms of those groupings. A final section discusses additional factors identified by the committee that have contributed to recent accidents.

Personnel

The personnel situation in the U.S. maritime industry is one of the most complex aspects of the safety problem. Many believe that U.S. seamen are among the best in the world and that their performance meets the highest standards. Certainly, the United States has strict personnel regulations, but their effectiveness is open to question. Several European nations have better accident records and what are judged to be more proficient maritime labor forces.

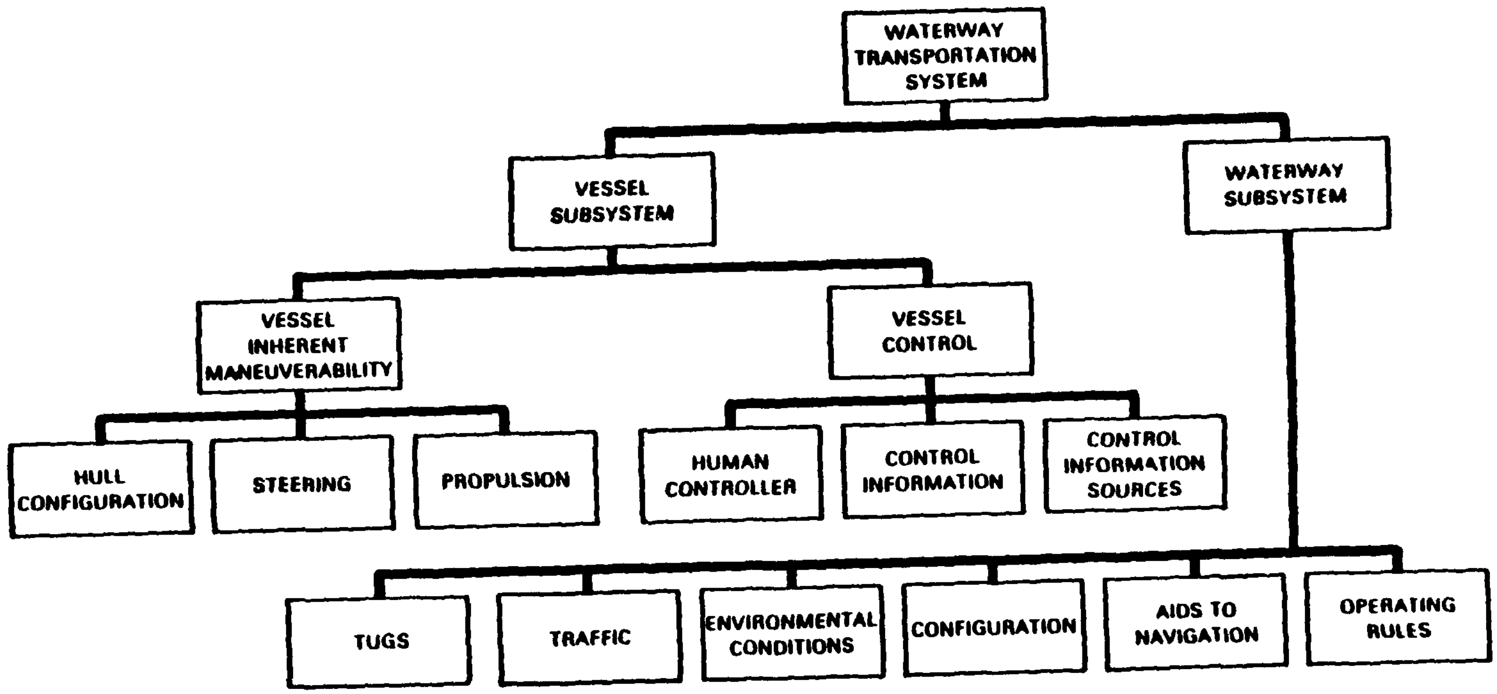


FIGURE 1 Factors influencing shiphandling.

The personnel problems faced by the U.S. maritime industry include the need to ensure adequate manning of vessels; the need to improve training procedures for young officers; and the need to correct the discrepancies in the application of legislation and regulations.

The avoidance of collisions, rammings, and groundings depends directly on adequate manning in all relevant departments. To do their jobs properly, seafarers not only must be well-trained and conscientious but also well-rested and alert. Competent people are needed to ensure safe navigation and vessel operation; to do underway maintenance of the ship and its machinery; to handle peak-load tasks such as mooring, getting under way, and emergencies; to provide flexibility in case of injury or sickness; and to operate the vessel manually, or to repair systems, in the event that automated gear fails. When manning does not cover these situations, excessive work hours could be required, resulting in fatigue and increased chances for a casualty.

Shipboard automation and unattended engine rooms may present another manning problem related to marine casualties. Advanced shipboard technology reduces the need for certain job classifications, but automation does not necessarily reduce the size of the crew. Technological improvements in shipboard machinery often do not reduce the crew's workload. Interviews with merchant seamen reveal that overtime on so-called automated vessels exceeds overtime aboard older ships. Breakdowns in automated systems on such vessels are not infrequent and create more work than on a nonautomated craft.

It is possible, however, to reduce safely the number of crewmen on an automated vessel. Decisions about manning requirements should be based on the trade-off between crew size and the reliability and cost of the machinery and control system. The key point here is that it is not always necessary that everything be done by a permanent crew. Proper control of the reliability of systems may be achieved by an operating crew and a temporary maintenance crew that rides the vessel at regular intervals.

The second critical area is officer training. Licensed officers for oceangoing vessels are promoted from within, hired from industry-sponsored schools, or hired after graduation from one of the six U.S. maritime academies. During 1979, these academies graduated approximately 900 officers; they entered the most favorable job market since 1944.

The majority of the senior officers on U.S.-flag vessels went to sea during or following World War II. Although lacking in formal education, they have extensive experience, especially in engine-room operation and maintenance, shiphandling, and seamanship.

The younger group--graduates of maritime academies and industry schools--have better formal education. However, they enter their

initial employment in far different positions and circumstances than either the older category of officers or other technical graduates hired from the nonmarine business world. These different circumstances are not to the advantage of either the industry or the maritime graduate. Means should be found for improving opportunities for on-the-job training to prepare new personnel for management or stewardship of their departments or vessels.

Entry-level jobs ashore for college graduates are not generally at a management/supervisory level. On the other hand, the new third mate on his first voyage is expected not only to stand watch but to assume management/supervisory duties as well. Ashore, supervisors work with new graduates in various ways and in general help them to take on more responsibilities. On large oceangoing vessels, the traditional system does not allow young officers to obtain such training and practice in the principles of supervision and stewardship. Some believe that greater attention to the supervision of young officers as they gain shipboard experience would result in better qualified watchstanders and safer operations.

The inland-waterway and offshore-service industries have special manning problems. A major issue is the apparent tendency of the government to consider manning problems in these industries identical to those in ocean shipping. For example, the industry claims that the Coast Guard's service-time requirements and licensing examinations reflect the needs of oceangoing vessels and are not really appropriate for tugs and barges, fishing vessels, and offshore service vessels. Yet, these craft account for a significant portion of coastal and inland maritime activity, and the differences among the various trades are sizable.

Neither the inland trade nor the offshore-service trade operates large ships, and the duties of the officers and sometimes the deck crew are different than on oceangoing vessels. On an oceangoing vessel, the captain and deck officers are supervisors, directing the work of an unlicensed crew and navigating the vessel over extended periods away from landmarks. On an inland towboat or offshore-supply vessel, the jobs of the captain and pilot are "hands on"; they operate the wheel and throttles rather than directing someone else to do so. On riverboats and offshore-service vessels, unlicensed crewmen learn shiphandling duties more quickly than on ocean ships because of the frequency of operations. Most voyages last a day or two rather than months. Also, most maintenance is reserved for port or shipyard periods, while maintenance is a primary duty of the crew on an oceangoing ship at sea.

Such differences in personnel functions, combined with inland-waterway and offshore job markets in which manual skill is still more important than academic knowledge, are factors in the shortages of licensed and unlicensed personnel in these industries. Manning shortages, of course, decrease safety margins.

Every port in the United States requires a pilot for vessels of more than a specified tonnage. The pilotage system in this country is steeped in local traditions. Practices vary from port to port as do the requirements for licenses and the competency of the pilots themselves. Pilots begin as apprentices and are trained on the job, from vessel to vessel. Simulator work on particular classes of vessels could upgrade the pilot-training process and reduce the numbers of collisions, rammings, and groundings of new types of vessels, particularly those of higher tonnage.

Ports and Waterways

Of all the constraints on a country's waterborne commerce, the greatest is the natural size and depth of its ports. Across the spectrum of waterborne commerce, the greatest single cost is that of significantly modifying a harbor channel, river, or other estuary. In the contiguous United States, only one harbor has an entirely natural passage to the coastal zone. That harbor is Seattle; the depth over the bar is 40 meters. All other U.S. harbors must employ considerable dredging to deepen and maintain their natural entrances. When undertaking such dredging, judgments must be made about the costs and expected economic benefits.

Economics is not the sole consideration, of course; safety is also crucial. In assessing ports and channels, the variables that must be considered include the hydrodynamic characteristics of the area. Ports vary in the period and length of their waves, current velocities, wind velocities and effects, tides, surges, and harbor seiches. Each of these variables is reviewed briefly below.

A survey of major U.S. harbors indicates that they experience waves with a predominant period of 8 seconds. Waves of an 8-second period are about 100 meters long in water deeper than half the wave length; they are shorter in water shallower than half the wave length. Because the dimensions of large ships considerably exceed the length of short-period waves, these larger vessels usually exhibit negligible roll and pitch. However, ports that frequently have a combination of high wind velocity, unfavorable wind direction, long fetches, and deep water may produce longer waves and excessive roll, pitch, and heave. These effects must be taken into account in channel design because they can hamper vessel control.

Current velocities vary greatly from port to port. They can range from zero to more than 2 meters per second, and currents can come from any direction relative to the channel centerline. The course stream, velocity, and direction of the current are all important when gauging the width of the channel needed and the sizes of the vessels that can traverse it safely.

The major factor affecting channel depths in U.S. ports is tide. Using tide and current tables, water depths and tidal currents are reasonably calculable in advance, which makes it possible to increase safety margins.

Harbor surges and seiches also should be considered. Surges are sizable waves or water masses, usually caused by meteorological phenomena. Seiches are periodic or oscillating waves inside the harbor basin generated by seismic or atmospheric disturbances. Surges and seiches can raise as well as lower the water levels. However, U.S. wave patterns generally do not exert a major influence on water depth or harbor safety and therefore are considered of minor importance to navigation.

Channel configuration is another prime consideration. The length of a channel to any port usually depends on the depth of the sea near the coast. Not only is the length of the channel important, but the number and tightness of the bends it contains can be critical.

Nevertheless, the major constraint on the safety of navigation of any channel is still the depth of that channel. The safety of a channel's depth for a given vessel must be assessed on the basis of interrelated variables, including the following:

- Changes in draft and trim of the ship caused by hydrodynamic and density changes;
- Tide;
- Meteorological disturbances of water levels;
- Ship movements under wave conditions;
- Desirable keel clearance; and
- Type of bottom.

Most U.S. harbors have a maximum allowable draft for vessels based on any one, or any combination, of the above variables. The following drafts are listed for reference:

Long Beach, California	18.3 meters
New Orleans, Louisiana	12.2 meters
Chesapeake Bay	12.1 meters

If we accept the premise that channel width should be determined by the dimensions of the largest vessels transiting the channel, and compare all U.S. ports and waterways with the sizes of the vessels using them, we would find little correlation. If, however, the rules governing traffic on those waterways are examined, there is a correlation to the extent that the speed and/or numbers of vessels

transiting narrow or congested waterways at any one time are limited either by custom or by statute. Therefore, in a strictly technical sense, it becomes necessary either to fix the position of each vessel accurately or actually to control the movement of all vessels so that all of the constraints of the waterway are met. Of course, tugs and pilots perform critical functions in this respect.

Although tugs are important to the safe movement of vessels, tug assistance in U.S. ports is nonstandard. Often, the quality of available tug assistance depends on the amount of traffic and the sizes of the ships that the port serves consistently. To be sure, advances in design have significantly increased the bollard pull per horsepower that the newer tugs can produce. Still, the number of tugs required to maneuver a ship will depend on wind, tide, and other factors, as outlined previously.

It should be noted also that many inland waterways employ tugs of up to 10,000 horsepower to operate barge tows that may be more than 1,000 feet long. Often, control of such tows around bends is difficult, and the bend must be clear of traffic because the tug and barge will sweep the width of the channel while turning.

Finally, the man-made structures in most harbors are becoming increasingly incompatible with the dimensions and maneuvering characteristics of current forms of marine transport. Most fixed structures--bridges, piers, etc.--in harbors are designed for a life of 50 to 75 years. Ships, on the other hand, are designed for a shorter lifetime. Thus ships may go through several generations of development and upsizing without consequent changes in the port and harbor facilities. In the last 20 years ship and barge sizes have markedly increased, decreasing the margin for error in passing situations and in maneuvering around harbor structures. Ramming of fixed structures is a major problem in today's harbors.

A related problem involves the rapid evolution of specialized types of shipping (LASH, RO-RO, LNG, etc.). Harbor design and construction tend to lag behind ship support requirements, and hence new forms of marine transport are often forced to use inappropriate facilities.

Aids to Navigation

Aids to navigation are designed expressly to help ensure vessel safety. They fall into three major categories: buoys and ranges; electronic position-fixing systems; and vessel traffic control systems. In each category a number of improvements are needed.

Most U.S. ports and waterways have, or had, fairly good systems of buoys and ranges. Many operators in the United States feel that maintenance and upgrading of existing systems would do more to prevent

collisions, rammings, and groundings than would more sophisticated systems proposed to improve traffic control. However, many operators also agree that development of more sophisticated traffic-control systems, designed with user input and offering more accurate position fixing, would certainly help to reduce such casualties. Nevertheless, existing buoy and range systems should be properly maintained or improved as a first priority.

The Loran-C system of position-fixing covers most U.S. ports and waterways. This system is established and maintained by the U.S. Coast Guard and accurately fixes a vessel's position in bays and sounds. For navigating narrow channels, however, Loran is not considered adequate because the channel widths are usually less than its limits of accuracy.

A number of vessel traffic service (VTS) systems currently are in use in some U.S. ports. Additional VTS systems are being proposed. Each of these systems is unique, and their degree of success is hard to evaluate at this time. Nevertheless, it is apparent that a traffic-reporting or -control system, designed and operated with user input, could reduce collisions, rammings, and groundings.

Vessel Characteristics, Maneuverability, and Hydrodynamics

The role of the inherent maneuverability of vessels must be placed in proper perspective if accident factors are to be identified correctly. However, it is difficult to identify those accidents in which inherent maneuverability is a factor. Vessel characteristics that affect maneuverability can be subdivided into those associated with steering and propulsion systems and those associated with hull configuration and vessel hydrodynamics.

Propulsion and Steering: Propulsion and steering systems are designed to meet three main criteria. They must fit into the hull, produce the desired speed, and produce the necessary rudder rate. Designers give little consideration to maneuvering and control of the ship as a whole. As a result, accident investigators can readily identify failures in propulsion and steering systems, but they cannot assess the performance of these systems in terms of vessel maneuverability.

Recent collisions and groundings, particularly the stranding of the AMOCO CADIZ, have demonstrated that steering systems are insufficiently reliable. In recognition of this need, IMCO is completing new safety standards designed to increase significantly the reliability of steering systems.

Failures of propulsion systems have not been a major factor in collisions, rammings, and groundings. However, some casualties can be

traced to failure of boiler-automation systems, and others to failure of the control mechanism associated with controllable-pitch propellers.

Hydrodynamics and Maneuverability: The maneuvering characteristics of vessels would intuitively seem to affect the numbers of collisions, rammings, and groundings, as previously noted, but the degree to which they actually do so has yet to be determined. Cases exist where a vessel clearly has run aground or collided with a moored vessel because it could not maneuver within fixed bounds, as in a river. Excluding such clear cases, however, it is not possible to determine the overall effect of maneuverability on casualties. This is so partly because of ignorance of the intermixture of possible causes listed elsewhere in this chapter, but also because hydrodynamic knowledge is insufficient to determine with guaranteed accuracy the inherent maneuverability of vessels.

Predictions of ship-maneuvering ability, or vessel tracks, are based on equations developed from Newton's laws of motion coupled with empirical coefficients. Once the form of the equations has been established, it is only necessary to determine the coefficients that relate the force and moment on the one hand to the motion variables on the other. The unknown coefficients in the equations generally must be obtained by experiment with models or by full-scale trials.

Current equations for determining maneuverability have been developed for deep, unrestricted water. The effect of restricted water, as in a port or channel, on the coefficients has yet to be determined. Yet, every experienced master knows that his ship is more difficult to turn in shallow water than in deep water; the minimum turning radius may be doubled in shallow water. Since the majority of collisions, rammings, and groundings occur in restricted or shallow water, the need to upgrade hydrodynamic knowledge and data is obvious.

The equations of motion cannot be used alone to help prevent accidents or to examine the effects of maneuvering on accidents because the equations do not take into account any of the other causal factors. The need to study the effects of the intermixture of all causal factors has led to the development of the ship simulator.

Simulators: A ship simulator is a model, most often a digital and/or analog computer, that is used to solve equations that describe the motion of a ship through its environment. The real world of the ship, the surrounding water, channels, etc., are replaced by the computer. The simulator may work in "real time"--that is, at the same rate as for a real ship--or at a much faster rate. If the simulator works in real time, a person can be coupled into the mathematical model, and the interactions of man and the ship/environment system can be studied. Such simulators are used for training and research in a variety of fields. They are particularly suitable for research and

training designed to improve ship safety while under way, mainly in restricted waters, and thus can be used to reduce the incidence of collisions, rammings, and groundings. Simulators also can be used to replicate accidents and thereby help to determine the causes of collisions, rammings, and groundings.

In simulating maneuvering, the simulator uses the aforementioned equations of motion to determine the ship's path. Where the equations are weak, the simulation is also weak. Indeed, shiphandlers comment that simulators do not reproduce the real-life handling and maneuvering characteristics of their particular vessels. More research is needed to gain the hydrodynamic data, thereby strengthening the equations of motion and thus the simulators.

To review briefly the case for more research, it has yet to be determined that improved maneuvering ability would reduce accident rates. Yet, intuitively this would seem to be the case. The lack of hydrodynamic knowledge and data casts doubt on the accuracy of the equations of motion in predicting maneuverability. Therefore, the effects of maneuverability on individual collisions, rammings, and groundings cannot be determined accurately. It has been established that the best way to study such casualties, with a view toward improving ship safety, is by simulator. However, because hydrodynamic data and knowledge are lacking, faithful simulation of ship-maneuvering responses cannot be guaranteed. This downgrades the usefulness of the simulator in assessing the effects of the interrelationship of all factors--e.g., human, instrumentation, maneuvering, etc. It therefore downgrades the usefulness of simulators in studies designed to determine means of reducing collisions, rammings, and groundings.

Other Contributing Factors

The committee reviewed 11 of the 26 reports by the National Transportation Safety Board (NTSB) on major marine casualties for the period 1976-1979 to check the causes officially assigned to these accidents. Four of the casualties reviewed were rammings and seven were collisions.

Of the four ramming cases, two were caused by steering failures; one by control-system failures; and one by a combination of errors in judgment, inadequate information, and unexpected current and hydrodynamic effects. The causes of the collisions included inability to process the available information in a timely manner (three cases); excessive speed (two cases); and one case where the vessel was on autopilot and the master was absent from the wheelhouse. A contributing factor in all cases was human behavior, including errors in judgment, failure to take action, inability to assess the situation, acting on insufficient information, confusion over legal requirements, and, in the one collision, intoxication.

Although failure to communicate was listed as a contributing factor in only two of the 11 NTSB cases reviewed, the committee found that poor communication was an important problem. Papers presented at an MTRB symposium on piloting and vessel traffic service (VTS) systems also stressed this issue.[4]

Communications problems may range from equipment failure to simple failure to use the equipment. Poor radio discipline and overcrowding of radio channels occur frequently on the Gulf Coast and inland waterways. The Federal Communications Commission publishes marine-radio procedures, but they are taught only in formal school programs; on small vessels, most of the training is on-the-job. Also, recreational boaters frequently violate marine-radio rules and procedures. Finally, there is no universal language for the maritime industry; this is a particular concern to the United States because more than 90 percent of the ocean shipping in our ports carries foreign flags.

The committee's review of broad categories of the waterway transportation system to identify causes of collisions, rammings, and groundings made it apparent that some systematic approach is needed for assessing the relative importance and interrelationships of causal factors. Chapter IV describes such an approach based on the development of functional-flow block diagrams.

CHAPTER IV

ANALYSIS OF CAUSAL FACTORS

The committee felt that one of the most positive contributions it could make to an assessment of research needed to reduce collisions, rammings, and groundings would be to develop a graphical analysis of causal factors. The methods used and the resulting functional-flow block diagrams are presented in this chapter.

Method for Determining Casualty Causal Factors

If research is to be used to reduce maritime casualties, specific research activities must be related to what are currently believed to be the causes of maritime casualties. To develop this relationship, the following steps must be taken:

1. Identify every possible factor or hazard that contributes to a collision, ramming, or grounding.

2. Evaluate each factor identified for its relative significance to marine casualties.

3. Rank each factor evaluated by its measure of significance in a continuum ranging from most to least consequential.

4. Obtain data on existing and imminent research projects related to causal factors in casualties.

5. Align the research information of item 4 with the ranked factors of item 3.

6. List in descending order of significance those causal factors for which no research is planned or under way.

The approach used by the committee to identify all possible factors or hazards that contribute to maritime collisions, rammings, and groundings consisted of two major tasks: preparation of a functional-flow block diagram (FFBD) for each type of maritime operation, and assembly of a list of casualty causal factors for every operational function in the FFBDs.

The committee assumed that current research into the causes of maritime casualties is based on the interests of either the agency requesting and funding the research or, in the case of unsolicited research, the proposing party. In other words, research is unlikely to be under way on all causal factors. Some factors, particularly those involving mechanization or hardware, are often nearly researched to death. Others, especially those associated with human behavior, are rarely treated as research topics. Figure 2 defines six major categories that must be addressed by research if maritime casualties are to be brought under control.

The committee used a systems approach to its review of research needs to ensure that all possible factors leading to maritime accidents would be considered as potential research subjects. The systems approach requires first a clear and precise statement of all functions (tasks or activities) being performed. The most common means of describing such functions is a diagram that depicts each function in a separate box or block. These blocks are then arranged in the order of their occurrence and connected by arrows. This diagram is called a functional-flow block diagram or FFBD.

The committee prepared one FFBD each for operations on an ocean voyage (Figure 3); on inland waters, particularly rivers (Figure 4); and on the Great Lakes (Figure 5).

The FFBD does not answer all of the traditional questions: who, why, where, or how? It simply describes what is being done. Further, the inputs to any task or activity are shown on the left and the outputs on the right. Thus, any given activity is separated into its constituent functions so that the nature, proportion, and interrelationship of the functions can be seen. The FFBD graphically shows the interdependence of all elements.

This application of the FFBD methodology ensures that every activity or task in maritime operations can be considered in relation to collisions, rammings, and groundings. Any such accident can be viewed as a failure to properly carry out an FFBD-defined function. Since the FFBD is a single, complete display of all essential functions, the possibility of overlooking casualty causal factors is vastly reduced. Thus, a holistic mechanism that interrelates all marine-casualty causal factors has been created--and for the first time, so far as the committee is aware.

Systematic Listing of Causal Factors

Once the FFBDs were developed, the committee was able systematically to list causal factors for collisions, rammings, and groundings. Initially, at a meeting of the full committee, each member was asked to respond to each individual functional box of the FFBDs in one of two ways: by recalling known causal factors in a

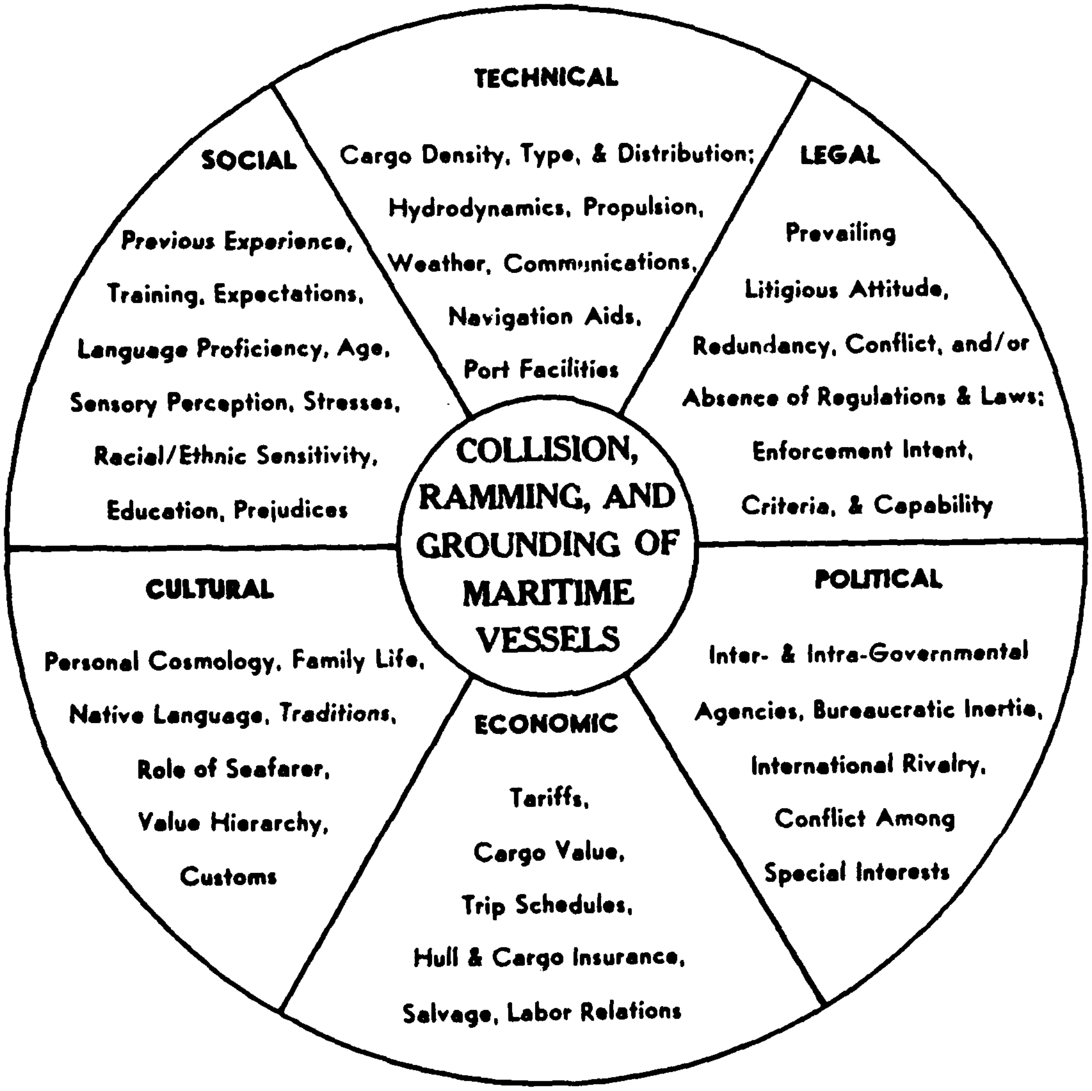
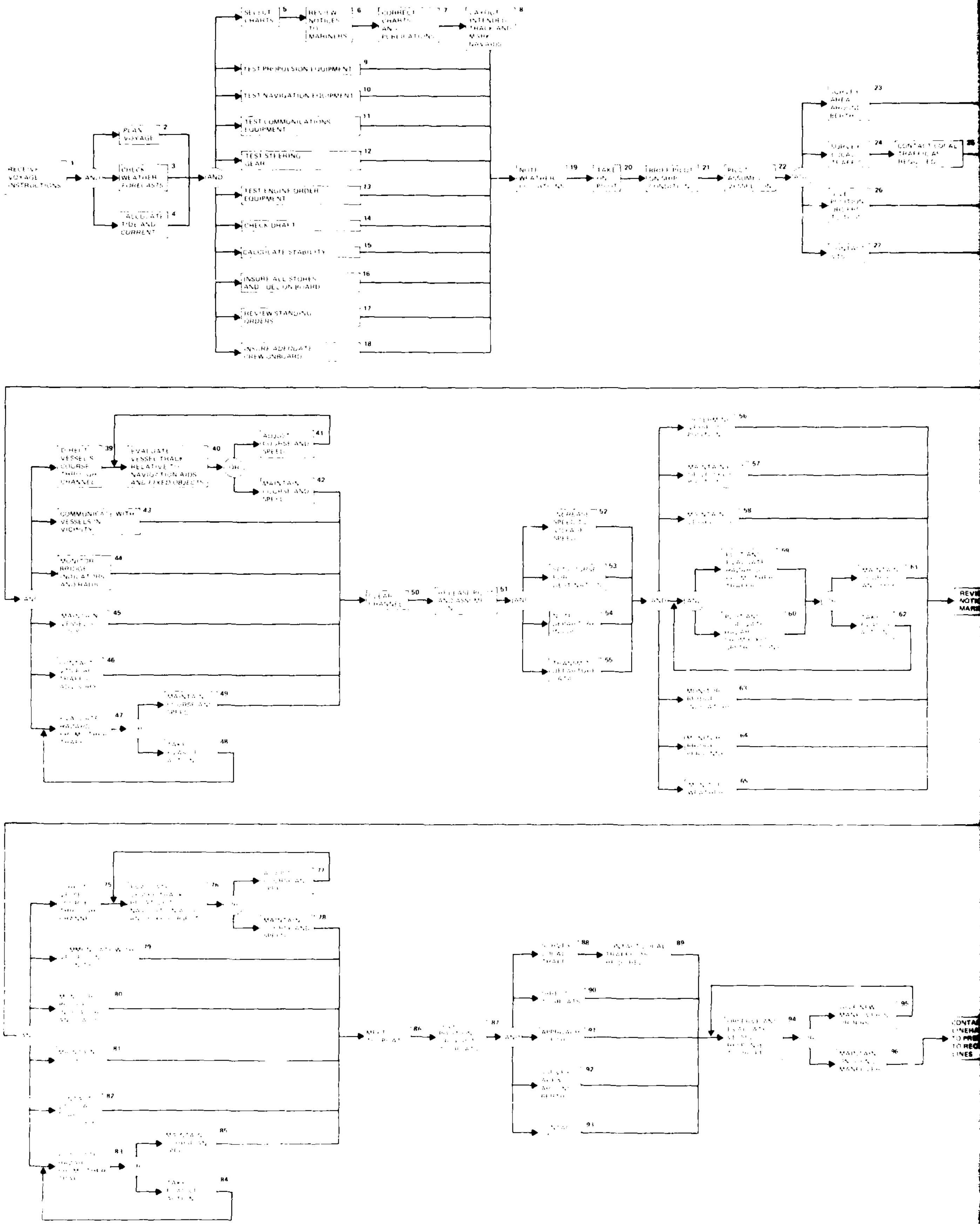


FIGURE 2 Facets of a systems approach to maritime casualties.



RECEIVE VOYAGE INSTRUCTIONS
AND
PLAN VOYAGE
CHECK WEATHER FORECASTS
CALCULATE TIDE AND CURRENT
AND
SELECT CHARTS
REVIEW NOTICES TO MARINERS
CORRECT CHARTS AND PUBLICATIONS
TEST PROPULSION EQUIPMENT
TEST NAVIGATION EQUIPMENT
TEST COMMUNICATIONS EQUIPMENT
TEST STEERING GEAR
TEST ENGINE ORDER EQUIPMENT
CHECK DRAFT
CALCULATE STABILITY
INSURE ALL STORES AND FUEL ON BOARD
REVIEW STANDING ORDERS
INSURE ADEQUATE CREW ONBOARD
CONTACT LOCAL TRAFFIC AS REQUIRED
DIRECT VESSEL'S COURSE THROUGH CHANNEL
EVALUATE VESSEL TRACK RELATIVE TO NAVIGATION AIDS AND FIXED OBJECTS
OR
ADJUST COURSE AND SPEED
MAINTAIN COURSE AND SPEED
COMMUNICATE WITH VESSELS IN VICINITY
MONITOR BRIDGE INDICATIONS AND RADIOS
MAINTAIN COURSE AND SPEED
AND
AND
MAINTAIN COURSE AND SPEED
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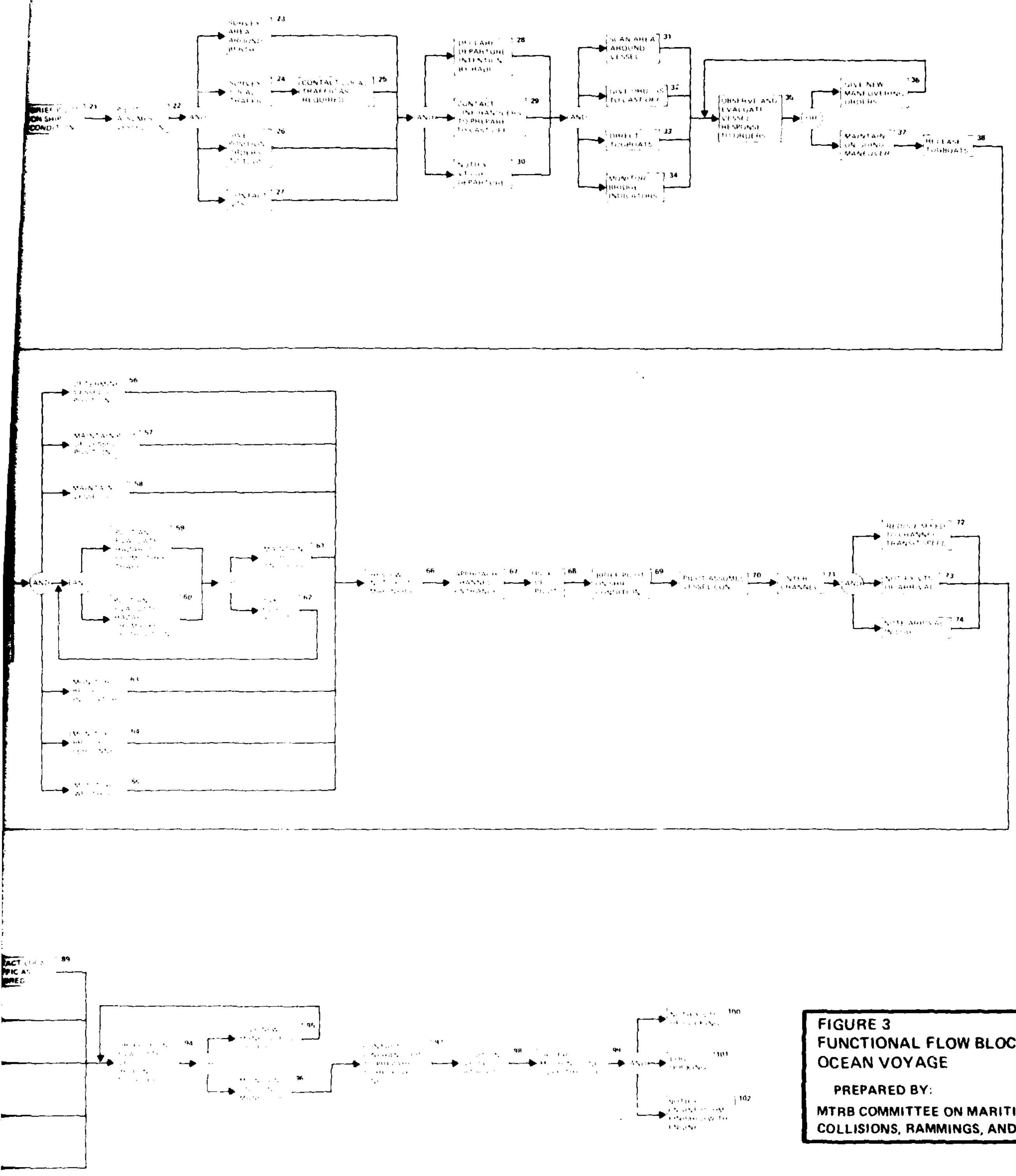
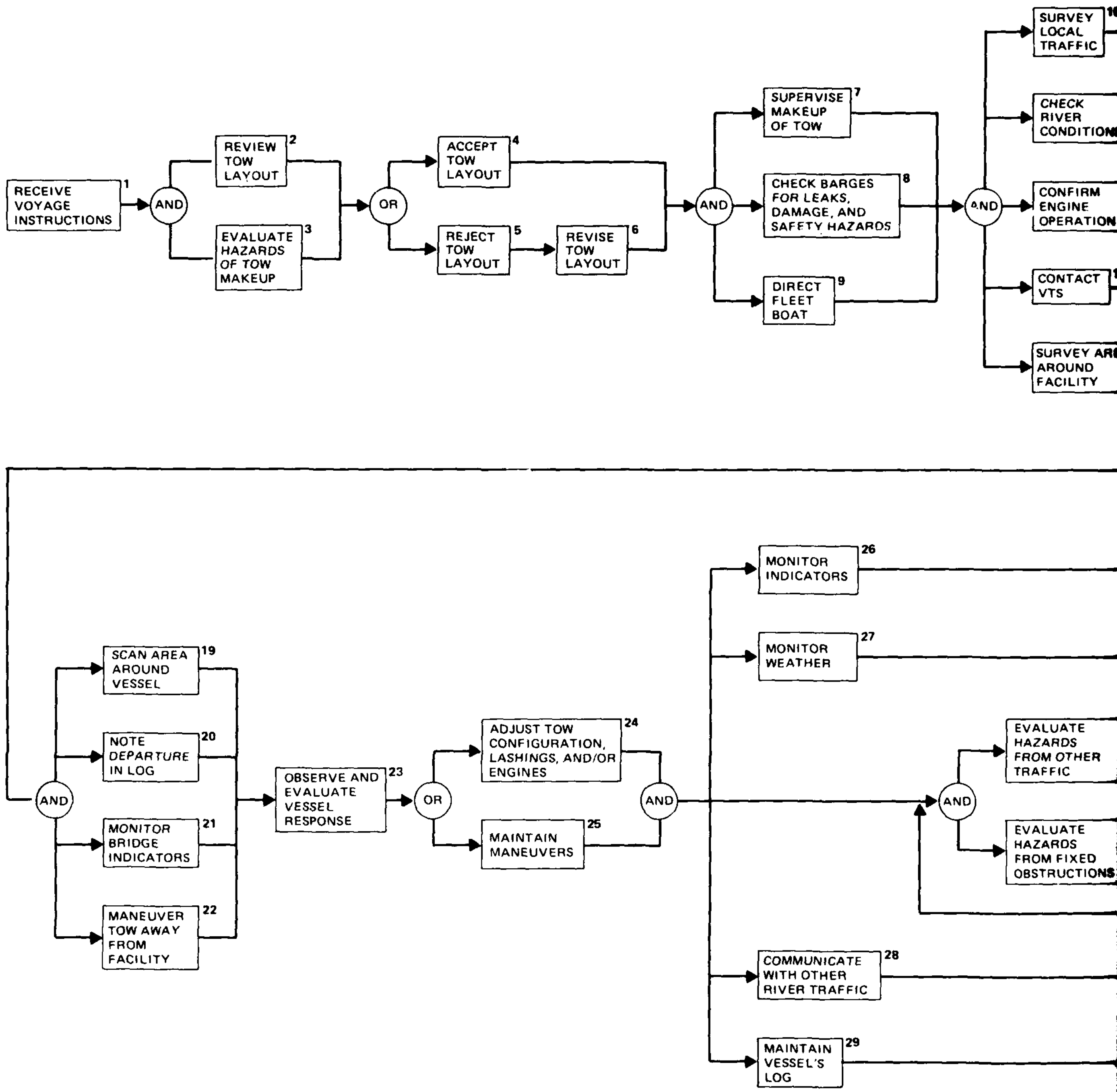


FIGURE 3
FUNCTIONAL FLOW BLOCK DIAGRAM
OCEAN VOYAGE

PREPARED BY:

MTRB COMMITTEE ON MARITIME COLLISIONS, RAMMINGS, AND GROUNDINGS



RECEIVE VOYAGE INSTRUCTIONS 1
AND
REVIEW TOW LAYOUT 2
EVALUATE HAZARDS OF TOW MAKEUP 3
OR
ACCEPT TOW LAYOUT 4
REJECT TOW LAYOUT 5
REVISE TOW LAYOUT 6
AND
SUPERVISE MAKEUP OF TOW 7
CHECK BARGES FOR LEAKS, DAMAGE, AND SAFETY HAZARDS 8
DIRECT FLEET BOAT 9
AND
SURVEY LOCAL TRAFFIC
CHECK RIVER
CONFIRM ENGINE OPERATION
CONTACT VTS
AROUND FACILITY
AND
SCAN AREA AROUND VESSEL 19
NOTE DEPARTURE IN LOG 20
MONITOR BRIDGE INDICATORS 21
MANEUVER TOW AWAY FROM FACILITY 22
OBSERVE AND EVALUATE VESSEL RESPONSE 23
OR
ADJUST TOW CONFIGURATION, LASHINGS, AND/OR ENGINES 24
MAINTAIN MANEUVERS 25
AND
MONITOR INDICATORS 26
MONITOR WEATHER 27
AND
EVALUATE HAZARDS FROM OTHER TRAFFIC
EVALUATE HAZARDS FROM FIXED
COMMUNICATE WITH OTHER RIVER TRAFFIC 28
MAINTAIN VESSEL'S LOG 29

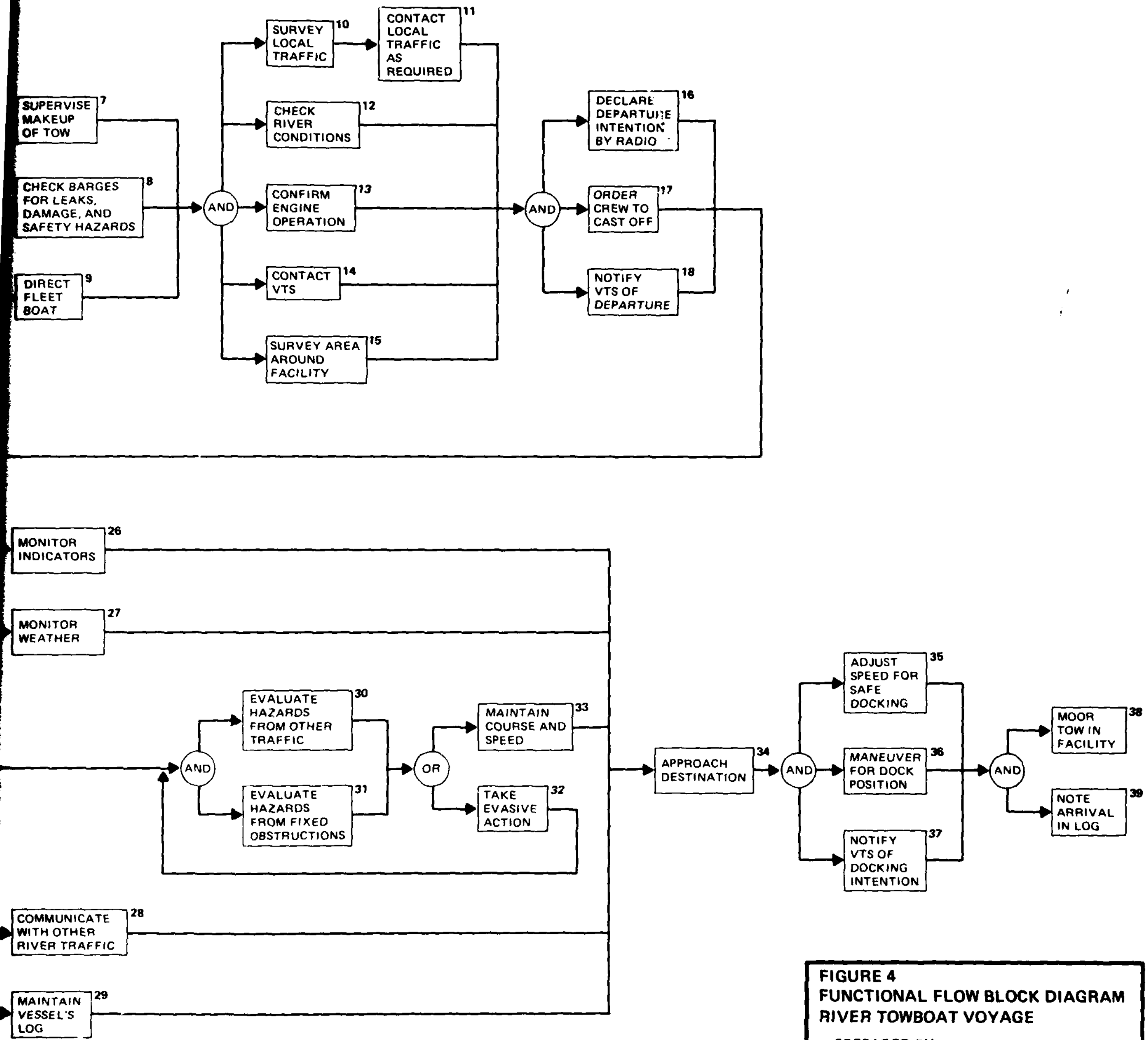


FIGURE 4
FUNCTIONAL FLOW BLOCK DIAGRAM
RIVER TOWBOAT VOYAGE

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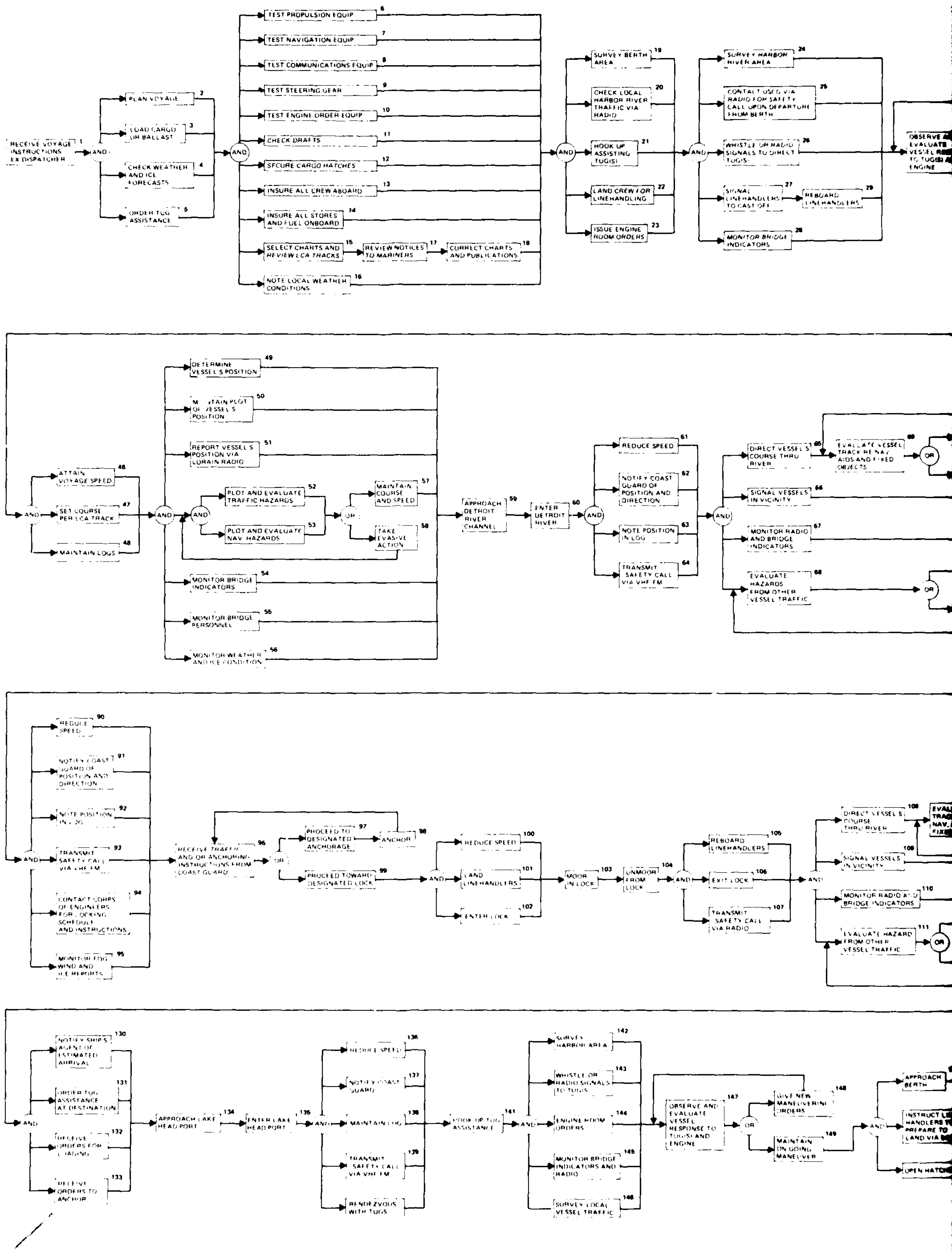

RECEIVE VOYAGE INSTRUCTIONS EX DISPATCHER 1
AND
PLAN VOYAGE 2
LOAD CARGO OR BALLAST 3
CHECK WEATHER AND ICE FORECASTS 4
ORDER TUG ASSISTANCE 5
TEST PROPULSION EQUIP 6
TEST NAVIGATION EQUIP 7
TEST COMMUNICATIONS EQUIP 8
TEST STEERING GEAR 9
TEST ENGINE ORDER EQUIP 10
CHECK DRAFTS 11
SECURE CARGO HATCHES 12
INSURE ALL CREW ABOARD 13
INSURE ALL STORES AND FUEL ONBOARD 14
SELECT CHARTS AND REVIEW LCA TRACKS 15
NOTE LOCAL WEATHER CONDITIONS 16
REVIEW NOTICES TO MARINERS 17
CORRECT CHARTS AND PUBLICATIONS 18
SURVEY BERTH AREA 19
CHECK LOCAL HARBOR RIVER TRAFFIC VIA RADIO 20
HOOK UP ASSISTING TUG(S) 21
LAND CREW FOR LINEHANDLING 22
ISSUE ENGINE ROOM ORDERS 23
SURVEY HARBOR RIVER AREA 24
CONTACT USCG VIA RADIO FOR SAFETY CALL UPON DEPARTURE FROM BERTH 25
WHISTLE OR RADIO SIGNALS TO DIRECT TUG(S) 26
SIGNAL LINEHANDLERS TO CAST OFF 27
MONITOR BRIDGE INDICATORS 28
REBOARD LINEHANDLERS 29
OBSERVE AND EVALUATE VESSEL RESPONSE TO TUG(S) AND ENGINE
DETERMINE VESSEL'S POSITION 49
MAINTAIN PLOT OF VESSEL'S POSITION 50
REPORT VESSEL'S POSITION VIA LORAIN RADIO 51
ATTAIN VOYAGE SPEED 46
SET COURSE PER LCA TRACK 47
MAINTAIN LOGS 48
PLOT AND EVALUATE TRAFFIC HAZARDS 52
PLOT AND EVALUATE NAV HAZARDS 53
MAINTAIN COURSE AND SPEED 57
TAKE EVASIVE ACTION 58
OR
MONITOR BRIDGE INDICATORS 54
MONITOR BRIDGE PERSONNEL 55
MONITOR WEATHER AND ICE CONDITION 56
APPROACH DETROIT RIVER CHANNEL 59
ENTER DETROIT RIVER 60
REDUCE SPEED 61
NOTIFY COAST GUARD OF POSITION AND DIRECTION 62
NOTE POSITION IN LOG 63
TRANSMIT SAFETY CALL VIA VHF FM 64
DIRECT VESSEL'S COURSE THRU RIVER 65
EVALUATE VESSEL TRACK RE NAV AIDS AND FIXED OBJECTS 66
SIGNAL VESSELS IN VICINITY 66
MONITOR RADIO AND BRIDGE INDICATORS 67
EVALUATE HAZARDS FROM OTHER VESSEL TRAFFIC 68
REDUCE SPEED 90
NOTIFY COAST GUARD OF POSITION AND DIRECTION 91
NOTE POSITION IN LOG 92
TRANSMIT SAFETY CALL VIA VHF FM 93
CONTACT CORPS OF ENGINEERS FOR LOCKING SCHEDULE AND INSTRUCTIONS 94
MONITOR FOG WIND AND ICE REPORTS 95
RECEIVE TRAFFIC AND OR ANCHORING INSTRUCTIONS FROM COAST GUARD 96
PROCEED TO DESIGNATED ANCHORAGE 97
ANCHOR 98
PROCEED TOWARD DESIGNATED LOCK 99
REDUCE SPEED 100
LAND LINEHANDLERS 101
ENTER LOCK 102
MOOR IN LOCK 103
UNMOOR FROM LOCK 104
REBOARD LINEHANDLERS 105
EXIT LOCK 106
TRANSMIT SAFETY CALL VIA RADIO 107
DIRECT VESSEL'S COURSE THRU RIVER 108
SIGNAL VESSELS IN VICINITY 109
MONITOR RADIO AND BRIDGE INDICATORS 110
EVALUATE HAZARD FROM OTHER VESSEL TRAFFIC 111
NOTIFY SHIP'S AGENT OF ESTIMATED ARRIVAL 130
ORDER TUG ASSISTANCE AT DESTINATION 131
RECEIVE ORDERS FOR LOADING 132
RECEIVE ORDERS TO ANCHOR 133
APPROACH LAKE HEAD PORT 134
ENTER LAKE HEAD PORT 135
REDUCE SPEED 136
NOTIFY COAST GUARD 137
MAINTAIN LOG 138
TRANSMIT SAFETY CALL VIA VHF FM 139
RENDEZVOUS WITH TUGS 140
HOOK UP TUG ASSISTANCE 141
SURVEY HARBOR AREA 142
WHISTLE OR RADIO SIGNALS TO TUGS 143
ENGINE ROOM ORDERS 144
MONITOR BRIDGE INDICATORS AND RADIO 145
SURVEY LOCAL VESSEL TRAFFIC 146
OBSERVE AND EVALUATE VESSEL RESPONSE TO TUGS AND ENGINE 147
GIVE NEW MANEUVERING ORDERS 148
MAINTAIN ON GOING MANEUVER 149
APPROACH BERTH
OPEN HATCH

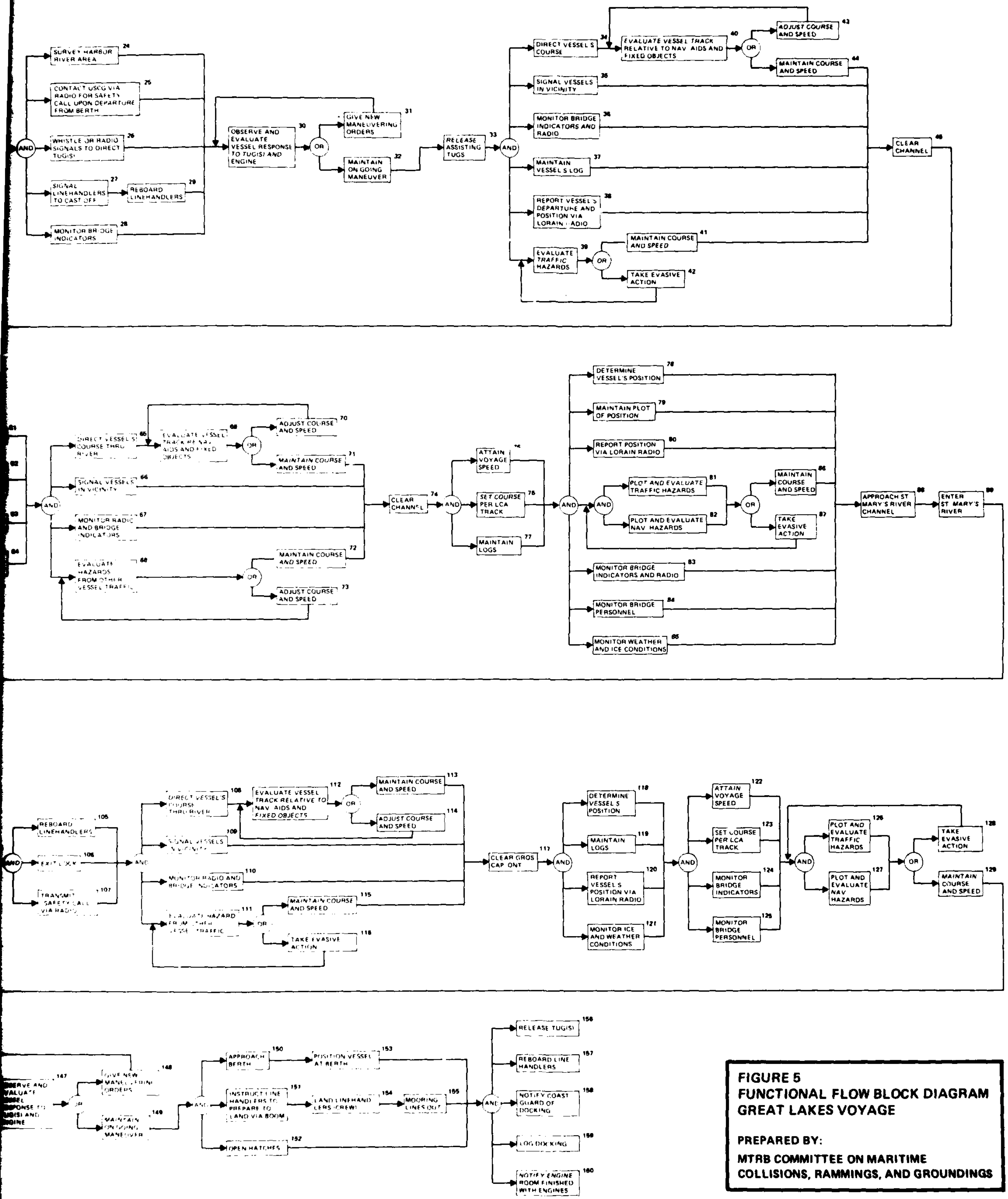

FIGURE 5
FUNCTIONAL FLOW BLOCK DIAGRAM
GREAT LAKES VOYAGE

PREPARED BY:

MTRB COMMITTEE ON MARITIME COLLISIONS, RAMMINGS, AND GROUNDINGS

maritime casualty pertaining to that function, or by postulating imaginable ways in which that function could be poorly performed and so contribute to an accident. A composite list of causal factors was then sent to committee members with experience in various aspects of marine operations. Each was asked to review the list for accuracy and plausibility and, from his personal knowledge of previous accidents, to augment and correct the initial list. The causal factors were then arranged so that each was aligned with at least one block in an FFBD.

Obviously, a single factor or hazard may contribute to the malperformance of several functions. In such cases, there are cross-references to several FFBD blocks. The important point of this correlation, however, is to ensure that no block in an FFBD is without at least one possible factor that has led or could lead to a collision, ramming, or grounding. Appendices A, B, and C contain the complete list of causal factors, which are then categorized in Appendices D, E, and F.

Even though the committee's goal was to include every possible maritime-casualty causal factor, the list is undoubtedly incomplete. Therefore, the work of the committee should be viewed as a foundation for a causal-factor data base that should be augmented continuously as missing or new information about maritime casualties is acquired.

The problems listed point to control tasks that are frequently of a high-risk nature. Further examination of the list indicates that most maritime casualties result from what is broadly categorized as "human error." It is clear that human actions that deviate from the expected standards and result in an unwanted situation predominate. The majority of these actions involve some degree of failure to perform a required task, take an appropriate action, or correctly evaluate the available information.

Isolation of Behavioral Factors

The committee attempted to isolate the behavioral components by constructing flow diagrams for the category "human error." The intent was to include, in sequence, all of the physical, physiological, psychological, emotional, organizational, and educational factors that might lead to that error. Although a number of flow diagrams were completed, the monumental nature of this task soon became apparent. Virtually every category of error studied could be shown to result from a mix of individual, low-order factors. As a result, it became evident that much of the literature of behavioral science would have to be explored for each error. Figure 6 is a small portion of one of these flow diagrams.

The construction of behavioral flow diagrams led the committee to recognize that the way in which human errors are conceptualized and categorized in maritime-accident investigations precludes easy entry

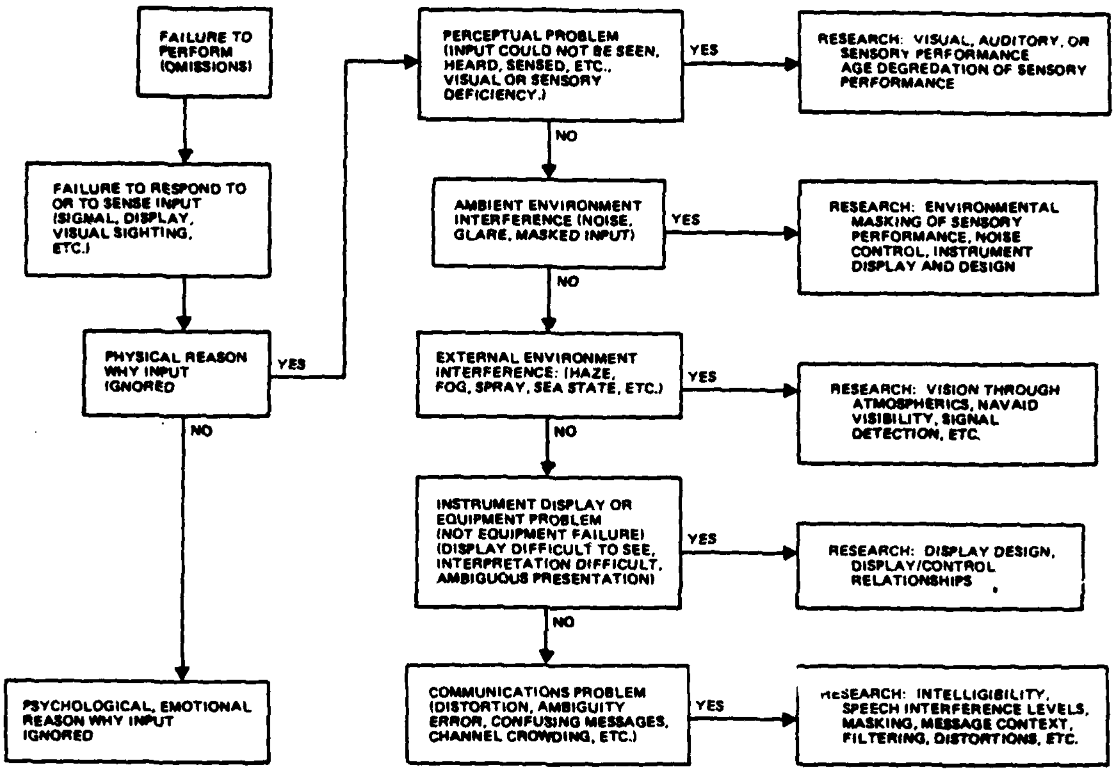

FIGURE 6 Partial flow chart for analysis of failure to perform.

into the accumulated research data base of the behavioral sciences. Further, tradition and legislation in the maritime industry have served to disguise the true nature of the man-machine relationship and have inhibited research into the causes of human error. While considerable attention has been devoted to human factors in modern modes of transportation, specifically aviation and motor vehicles, the committee feels that the maritime community is just beginning to realize the casualty-reduction potential of assessments of man-machine and man-man interactions.

To stimulate further examination of the human component in maritime safety, the committee felt that it was imperative to outline existing research on human error and to develop a perspective for future studies of human factors in the prevention of collisions, rammings, and groundings. Chapter V sets forth this discussion.

CHAPTER V

RESEARCH LITERATURE ON HUMAN ERROR

As work on the functional-flow block diagrams proceeded, it became apparent that the single most prevalent factor in maritime casualties is human error. Accordingly, an analysis of research on human behavior and variables contributing to human error in accidents was undertaken. This chapter describes the availability, accessibility, and applicability of research in the behavioral sciences that is relevant to the prevention of maritime casualties. It also explains how to gain access to the results of such research in relation to investigating a specific casualty.

Maritime operations are strongly dependent on human beings, and their abilities and limitations often become the controlling factors in system safety. Considering the accumulated information on human behavior and the antiquity of many maritime personnel problems, it would seem reasonable to assume that solutions to the problem of avoiding human error in maritime casualties would come readily to hand. This is not the case, however.

Certainly, the human-factors literature is rich enough. In 10 years of operation, for example, the Human Factors Engineering Analysis Center of the U.S. Department of Defense collected and cataloged more than 30,000 publications dealing with man-machine relationships. Many of these publications relate to maritime operations. Similar accumulations of data exist in related areas of accident research, safety, personnel, and organizational behavior.

The fact is that these data bases, rich as they are, are organized in a manner that makes it difficult to deal with complex, real-world problems, particularly those posed by operational personnel. The questions that practical persons ask are deceptively simple, yet enormously complicated in their implications. Such questions tend to be closely related to particular situations or tasks and usually are phrased in a problem-oriented format. The following examples are typical:

- What type of radar display is easiest to interpret in high-traffic conditions?

- How do you enforce communications discipline to minimize radio chatter?

- What is the best bridge arrangement for efficient operation and smallest crew size?

- How old is too old for a seaman?

Literature on such questions usually is based on information gathered to make a specific decision about a particular system. In most cases, the scope of the investigation was only sufficient to answer the question posed; and because research is expensive, sample sizes, ranges of conditions considered, and scientific rigor are insufficient to permit broad generalizations. For example, corporate libraries are full of studies commissioned to answer specific design or operational questions. Yet this work either fails to meet the standards for publication in professional journals or is not published for proprietary reasons. Nevertheless, these studies have significant merit; they accomplished their purposes. And despite the general unsuitability of most of them for publication, much of the material has found its way into print in one form or another.

Almost every issue of Marine Engineering Log, Marine News, Fairplay, or Shipping World contains articles suggesting that wheelhouses, wings, engineering spaces, etc., be redesigned. In addition, papers are read each year before chapters of the Society of Naval Architects and Marine Engineers. All of this material can be located through the Marine Research Information Service, which abstracts and disseminates the information via the Lockheed DIALOG system.

The literature does not, however, answer many of the practical questions. The information that might be required to answer some of these questions ranges from very basic data on human perceptual skills to complex and often confusing information about social values and organizational structure. For example, the question "How old is too old for a seaman?" requires not only data on the deterioration of performance with age, but the development of assumptions about the value of experience, labor relations, shipboard equipment, pension policies, etc.

Human-Factors Literature

The bulk of human-factors literature is human-performance data. It details the sensory, perceptual, cognitive, and physical performance of human beings. It tends to be task-oriented and deals with easily definable units of human behavior rather than the entire human experience. There is good reason for this. The more specific and constricted the unit of human behavior, the more trustworthy and

reliable the data; the broader the unit of behavior, the more ambiguous the data.

This orientation is clearly no accident. Behavioral science, particularly in areas dealing with human performance, has sought for more than half a century to exclude subjective and intuitive concepts from the discipline. Chapanis, in his text on human-engineering research techniques, set the tone for a generation of investigators by stating:

> We shall see that some ways of looking at human beings are so vague as to be useless, while others are meaningful and researchable. The general rule is that we can study human activities only by studying behavior, the things people do. We cannot study what they experience.[5]

Chapanis then encourages researchers to pursue only operational and behavioral aspects of behavior--those aspects that are observable and measurable.

A different approach to the study of human behavior is taken by many specialists in maritime safety, including previous panels of the National Research Council. Here broad behavioral areas, specific behavioral acts, causal factors of behavior, and the consequences of behavior are intermixed in a manner that safety specialists believe sheds light on accident causality. The specific terms used owe as much to tradition as to their value as explanatory concepts. Two examples are pertinent. A 1974 MTRB Panel on Human Error in the Merchant Marine stated:

> Through the deductive process, the Panel determined that human errors occurred through events involving one or a combination of the following primary causes:

1. Panic or shock	8. Fatigue
2. Sickness	9. Negative transfer of training
3. Drunkeness or drugs	10. Negligence
4. Confusion	11. Ignorance
5. Inattention	12. Calculated risk
6. Incompetence	13. Fear
7. Anxiety	

The final report of the panel cites inattention as the major human error precipitating maritime accidents.[3]

Another example, the USCG Marine Safety Manual (CG-495), gives detailed instructions on how to distinguish between faulty judgment and negligence in assessing the cause of a casualty.[6] It should be noted, however, that few of these terms describe behavioral acts. They are inferences or value judgements based on the consequences of a series of acts. Thus, a master who maintains speed in bad weather to

arrive on schedule is guilty of negligence only if he is unlucky enough to hit something or otherwise cause damage to his ship or cargo. Similarly, inattention to duty becomes a causal factor only in the event of an accident; inattention by a watch officer or helmsman under other circumstances might well be overlooked.

Does the foregoing mean that the behavioral literature is closed to accident research? Not at all. What it does mean is that the current concept of an accident as an unforeseen or chance event must be replaced by a concept of accidents as complex events involving a system of human and environmental factors. In this view, there is no single causal factor but rather a series of multiple factors composed of antecedents and precipitating events. The accident is conceived to occur during a chain of events that involves the introduction of some unexpected and unavoidable occurrence that precipitates an inappropriate response by at least one individual.

From this definition it can be seen that few events that are currently called accidents are really accidents in the sense of being purely chance events. Rather, accidents consist of that large class of events characterized by low predictability and controllability and undesirable consequences.

Examining the Literature

With this definition in mind, and recognizing the scientific limitations of accident research, it is useful to examine the literature to determine its relevance to the problem of preventing collisions, rammings, and groundings.

Accident-research literature has been organized into three broad categories (Table 3). The first of these, Accident Causation and Severity Research, probably accounts for most of the investigative effort and in the past has been the most successful. Research in this area requires little if any conceptual framework and involves few methodological problems.

NTSB and USCG accident investigations fall into this category. Generally speaking, in this first type of investigation it is possible to identify some set of agents, actions, or conditions that appear to be the "proximate causes" of an accident. Insofar as future conditions duplicate those of the accident under investigation, a variety of remedial actions can be taken. Of course, in this type of investigation, the identification of causes depends on what the investigator views as remediable.

The literature abounds in accident causation and severity research, not only in the maritime area but also in other forms of transportation and occupational safety. Yet, the usefulness of this body of literature in preventing accidents is limited. Much

TABLE 3 Accident Research Literature Areas

1. ACCIDENT CAUSATION AND SEVERITY RESEARCH

   A. Investigation and analysis of individual accidents. (NTSB, USCG reports.)
   B. Investigation of accidents by risk situation. (USCG statistical reports.)
   C. Investigation of accident generating situations or processes.

2. ACCIDENT PREVENTION RESEARCH

   A. Countermeasure development research.
   B. Countermeasure effectiveness research.
   C. Countermeasure acceptability research.

3. ACCIDENT-RELATED BEHAVIORAL RESEARCH

   A. General behavioral processes.

      Examples: Perception, relative motion perception
      Risk assessment
      Risk taking
      Learning and training
      Personality factors
      Attitude formation
      Vigilance and monitoring
      Cultural and social factors

   B. Specific behavioral processes.

      Examples: Alcoholism and performance reduction
      Formation of attitudes toward risk and safety
      Ageing and performance reduction

   C. Man-machine factors.

      Examples: Control and display design
      Bridge design
      Radar and communication equipment design.

investigatory work is motivated by the need for evidence for adversary proceedings; the published reports tend to be sanitized according to the rules of evidence of the investigatory body. In addition, such studies emphasize the severity of the consequences. There is no reason to suspect that severe maritime accidents result from different causes than mild ones. Finally, the studies usually offer remedies only for the proximate causes of the accident; they fail to deal with the psychological, social, physical, and economic environments that might continue to generate human failings that lead to accidents.

The second broad area in Table 3, Accident Prevention Research, is of comparatively little use in understanding the causes of accidents. Much of the literature describes the many accident countermeasure and prevention programs in existence. Although many of these programs probably have been effective, there is little research that explains why. Invariably, accident countermeasure programs are confounded with a variety of concurrent activities that contribute to accident reduction. Among these are personnel-selection programs, new-equipment procurement programs, legislation, and changes in operational procedures. Consequently, the literature is descriptive and, because of the confounding variables, is rarely rigorous enough to appear in scientific journals.

The final area, Accident-Related Behavioral Research, contains the most extensive body of work, but because of the conceptual problems described earlier it is the hardest to get at. The scope of this type of research, its availability, and its applicability to the analysis of any single maritime accident are considered in the following paragraphs.

Let us assume that the causal sequence of a maritime accident can be characterized by the same social and psychological forces that determine other types of behavior. Viewed in this fashion, any accident may be analyzed for the kinds of decision-making processes involved; the motivational forces; the cultural influences; the social interactions; the perceptual, learning, and training problems; and the problems of man-machine interaction. In short, the explanatory mechanisms that the behavioral sciences have developed for any form of behavior can be applied to accidents. The data base, then, includes the entire literature of behavioral science. Clearly, searching a data base that large is a monumental task.

The search can be limited by concentrating on the behaviors immediately antecedent to the accident. These include the perception of hazard; personality factors relative to risk-taking; attitudinal factors concerning safety; vigilance; fatigue; man-machine relationships; and organizational and social factors related to the efficiency of performance in a maritime situation. Only when consideration of these factors fails to explain the accident sequence should the scope of research be enlarged.

Accessibility of the Literature

Two major indices of behavioral-sciences literature exist and are suitable for use in accident research. The first is the cumulative index of publications in Psychological Abstracts, a monthly publication of the American Psychological Association.[7] Psychological Abstracts abstracts and indexes literature in the behavioral sciences from a variety of sources. It is the single, most comprehensive index of behavioral-science literature. Its disadvantage lies in its inclusiveness. By attempting to include virtually all behavioral literature published in referenced journals, it puts the burden of problem definition on the researcher. Psychological Abstracts indices have been computerized for the past decade; the American Psychological Association performs searches of the literature for a minimal fee. Access to the computerized index is available through the National Technical Information Service in Springfield, Virginia.

More directly relevant to the behavioral problems in accident research is the data base maintained by Professor Stanley Lippert of the School of Engineering, University of Massachusetts, Amherst. It incorporates the Tufts Bibliographies of Human Factors Literature,[8] sponsored by the U.S. Navy, for the years prior to 1967, and Ergonomics Abstracts[9] for subsequent years. This data base covers more than 40,000 documents more or less related to human factors. Each document is indexed and cross-referenced by a number of descriptive terms. An extensive number of sources of human-factors data is given in Appendix G. Appendix H, Selected Bibliography, contains additional references in its section on human factors.

Despite the availability of these indices and abstracting services, there is no large, publicly available, comprehensive document collection for either human-factors or accident-related research. Having found the relevant abstracts, the researcher must track down the original documents. There are various special-interest collections (Appendix G), but the task of locating specific documents may be, for some areas, more onerous than repeating the original research, particularly if the material is contained only in corporate or military progress reports.

The committee tested the availability of behavioral-science literature relevant to marine accidents by searching the Human Factors-Ergonomics data base at the University of Massachusetts. The results were illuminating: 340 titles of general human-factors bibliographies were obtained. Problems related to individual risk-taking and decision-making were covered in 249 titles. Personality factors affecting accidents were covered in 125 titles. Perception problems relative to accidents were covered by 136 titles. Performance under stress was covered by 131 titles. Set and attention were covered by 71 titles. Vigilance and monitoring were covered by 56 titles. In brief, a short search through the data base provided

1,759 references in the human-factors literature that dealt with some aspect of marine casualties.

In spite of the difficulties, the indexed behavioral-science literature can facilitate investigation of the causes of an accident to the extent that individual, accident-related behaviors can be identified and significant questions posed about them. The procedures are, or should be, similar to those used in industrial-engineering task analysis or industrial psychology; they involve a great deal of work, but the data are there. Finally, to search the behavioral-sciences literature for information relevant to a given maritime casualty requires multiple areas of expertise--e.g., an individual or group knowledgable about the terminology and concepts of both maritime and behavioral sciences research.

Supplementing the primary behavioral-research literature are a number of reviews dealing with occupational safety and health and published under the aegis of the National Institute for Occupational Safety and Health. The most recent, and probably the best, of these documents is the HEW publication, Problems in Occupational Safety and Health: A Critical Review of Select Worker Physical and Psychological Factors.[16] This publication reviews the scientific literature on the personal characteristics of workers in relation to their health and their safety on the job. Characteristics of primary concern were physical attributes, such as age and sex, and psychological attributes, such as personality and stress resistance. The publication contains summary reviews of the literature in areas involving age, sex, physical work capacity, alcohol and drug use, fatigue, personality and emotion, and life stress. Author and subject indices, citations, and abstracts cover more than 1,300 references.

Having assessed the availability, accessibility, and applicability of behavioral-sciences research, the committee noted distinct gaps in this basic information. The most important gap is the lack of attention to the concept of deliberate acceptance of danger or risk. This factor obviously is important in understanding behaviors antecedent to accidents, as well as in understanding the level of societal pressure for safety assurance.

There has been little deliberation and no consensus on the kinds and numbers of accidents our society considers it necessary to eliminate. The literature virtually ignores a key theme related to accident prevention: Chance-taking is a basic, fundamental American life goal. This attitude should be considered in the development of safety-education and accident-prevention campaigns.

Success stories throughout history have frequently defined people in terms of "courage," placing a high premium on taking chances. These themes are instilled in children and manifest themselves in adult behavior. A "heroic" adult may take a benign view of the dangers inherent in a given situation. It is not surprising,

therefore, that the maritime industry does not assume that freedom from accidents is a reasonable or even desirable goal.

The committee heard maritime officials state that acceptance of risk is so ingrained in the maritime psyche that it has become almost institutionalized as a way of life. The typical seaman makes two bets with regard to risk: "If danger comes, I can handle it," and "I am betting that danger has a low probability." This attitude mitigates against preparedness for a high-hazard situation.

Only a few references in the literature deal with acceptance of risk by organizations in the maritime community, even though many organizations have explored the consequences of such acceptance and become self-insurers. An important series of studies on organizational and individual risk-taking is Perspectives on Benefit-Risk Decision Making, published by the National Academy of Engineering.[11] But despite these illuminating studies, this area clearly needs further amplification.

In sum, the behavioral-science literature contains a wealth of material related to behaviors antecedent to accidents. The literature is strongest in those areas concerned with human-performance variables, such as perception, learning, thought processes, man-machine interactions, and physical and physiological factors. There is a significant gap in the literature in the area of acceptance of risk by individuals and institutions.

It is difficult to gain access to the material that is available, however, primarily because current concepts about accidents are incompatible with the manner in which the literature is encoded. When accidents are viewed in terms of their consequences, the literature is largely impenetrable. If accidents are conceptualized as sequences of human behaviors that lead to an undesirable event, the literature can be searched in terms of the component behaviors. Such an approach demands behavioral analysis: The operational problems of the real world must be broken into their component parts, which must be reassembled into a system-related whole.

Collisions, rammings, and groundings do not happen by chance. They are caused by people who do not respond properly to an event. The event may not be perceived accurately, there may not be enough warning, or there may be some other "interference"; nevertheless, a human failure has occurred. Some clear element of negligence or misjudgment also may be involved. The more loaded an event with each of these characteristics, the more likely it is that improper actions will be taken and will lead to what is labeled an accident. A program of research aimed at understanding the causes of these human errors is outlined in Table 4. Relatively little new research is required. What is needed is a recasting of available data into a more comprehensible format.

TABLE 4 Needed Research in Human Causal Factors in Collisions, Rammings, and Groundings

	Problem Description	Data Source	Research Required
1.	Identification of critical segments of marine operations leading to CRG. Isolation of equipment, environmental, operational, and organizational causal factors.	Existing NTSB, USCG accident investigations, USCG statistical reports, Insurance data.	Analysis of existing documentation.
2.	Specification of a conceptual model of an accident that takes cognizance of the behavior sequences leading to an unwanted event.	Current behavioral research on accidents. DOT research on driver behavior.	Development of acceptable behavioral models with operationally defined terminology.
3.	Collection of a Maritime human-factors research data base. Location and acquisition of abstract listings and source documents. Maintenance of a public data research facility available to industry and government.	MRIS, NTSB, USCG, SNAME, SAE, Trade journals, Navy, MARAD, Psychological Abstracts, Ergonomic Abstracts, DOT Safety Abstracts, etc.	Data collection, review, abstracting. Data base design. This is a task for library information science specialists.
4.	Identification and analysis of behavioral research in data base(s) relevant to critical segements of marine operations that lead to CRG or other unwanted events.	Data sources of 1 and 3. Data base of 3.	Exercise of conceptual model of 2 to identify accident-likely sequences of behavior. Identification of corrective or remedial actions or procedures.
5.	Research in behavioral, social, organizational, and economic areas that underly acceptance of risk in maritime operations.	Personality, social, behavioral research. Insurance data, marine economics data. Training. Legislation.	Currently available data should initiate research. Substantial new data required after initial phases.
6.	Research in promulgation of accident-reducing and/or ameliorating programs, legislation, training, and equipments. Embedding of safety research.	Political science journals. Industry sources.	Program evaluation research. Determination of why and through what mechanisms safety programs succeed or fail. Cost/benefit analyses of achieving safety.

CHAPTER VI

COLLECTION AND EXCHANGE OF INFORMATION

The extent of marine losses from collisions, rammings, and groundings, as well as the probability of larger losses in the future, demand immediate action. In addition to funding the needed research, practical measures should be taken promptly to terminate or minimize the threats these casualties pose to society. One such measure that would be very cost-effective is prompt dissemination of lessons learned from losses and near-losses.

The committee hopes that the maritime industry will consider some of the models for exchanging safety information that have been developed in aviation. Exchange of such information has been very important in improving aviation safety. Exchanges of experiences objectively and without making accusations or assigning blame also arouse interest in efficiency and safety among personnel. Such exchanges create a climate of continuous awareness of the nature of threats to safety. Further, they encourage a dialogue about anticipated risks. More "What if . . .?" discussions--i.e., situational problem-solving--should prove valuable in defining the needs for future investigation and research.

In any industry, effective exchange of information can become a reality only if it is desired by the potential users. In the maritime industry, potential users include naval architects, ship owners and operators, shipboard personnel, traffic controllers, and personnel in associated government agencies. The development of a well-structured plan to gather, analyze, screen, and disseminate information about casualties and near-casualties, as well as suggestions for minimizing casualties, will depend on cooperation throughout the industry and between industry and government.

The information might be disseminated in various formats--e.g., a version for the seaman and mariner, another for executives, another for engineers. Using the aviation industry as a model, the dissemination of information might also be organized according to type of operation: ocean, offshore, river, and harbor. Appendix I contains an example of such information exchanged in the aviation industry.

The committee recognized that legal questions, problems in management/employee relations, proprietary interests, and pride may inhibit the free exchange of information about preventing losses. This may be particularly true with respect to near-losses, which do *not require* mandatory reporting to authorities. Nevertheless, an objective exchange of information on prevention of maritime losses should be explored, and an appropriate method should be designed and implemented.

Models of Information-Exchange Systems

There are models available. The NASA/FAA Aviation Safety Reporting System, the International Air Transport Association Confidential Exchange, and the Flight Safety Foundation Accident Prevention Bulletins operate satisfactorily. In the maritime field, the International Chamber of Shipping, the Oil Companies International Marine Forum, and the Intergovernmental Maritime Consultative Organization (IMCO) could be responsible for an exchange of loss-prevention information. Several other organizations currently collect and disseminate accident/incident information. A study should be made to determine if the information is distributed properly to need-to-know users rather than allowed to drift onto shelves or into waiting rooms and libraries.

Impressive records of maritime-safety research and accident information are available from data bases such as those maintained by the National Technical Information Service, the Maritime Research Information Service, and the Safety Science Abstracts Journal. However, these data bases are geared to naval architects, marine executives, and scientists; they offer little practical advice for the operating mariner. The process for providing input to these data bases should be examined for completeness, currency, and relevance, especially in terms of providing more practical information on safety.

Needs in the Maritime Industry

Such structural improvements and ways to publicize information about reducing maritime losses to seagoing personnel should have high priority. Research results that simply guide future research efforts will not have an impact on today's problems; information must be disseminated much more widely than in the past.

Periodic conferences or seminars should be held to address specific safety needs of the various segments of the industry, to exchange information on losses and problems, to assign priorities, to define areas requiring cooperation between government agencies and industry, and to focus on the further development and implementation of research on improvements in procedures and techniques. Universities, research organizations, government, and

industry-sponsored institutions should participate in the sharing of information and the cross-fertilization of ideas.

In summary, the committee sees a need to establish a group responsible for the centralized collection, analysis, and prompt exchange of loss-prevention information with respect to collisions, rammings, and groundings. The effort should be at two levels: one for dissemination among ship owner/operators and seamen who work at the operational level, the other, comprised of research abstracts, for executives, designers, engineers, and marine researchers. In addition, the present sources of research information should be evaluated for completeness, adequacy of referencing, and accessibility. The collection of loss-prevention information based on losses and near-losses should conform to a format that might lead to the identification of needs for short- or long-range research or the trial application of remedies already available. It will be necessary to seek the most effective ways to accomplish these ends, assuming that the marine industry will cooperate. Improved intergovernmental and government-industry coordination will be required.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

The foregoing chapters have reviewed the findings of the committee. The conclusions and recommendations are given in the Executive Summary. The committee felt, however, that further explanation of its rationale in formulating these conclusions and recommendations would be useful to those concerned with marine safety.

Conclusion 1

The National Transportation Safety Board (NTSB) asserts that more than 75 percent of maritime casualties result from human failure, which covers the spectrum from complacency to incapacity, carelessness, neglect, and possibly surrender to pressure or to boredom. Studies of major casualties by marine underwriters have found as high as 85 percent human failure, again in a variety of forms. The committee concluded that:

1. The causes of maritime casualties are seldom technologically sophisticated or obscure. Almost without exception, the proximate or probable causes of collisions, rammings, and groundings are well known and widely recognized as some form of human failing. Yet there is little recognition or understanding of the underlying causes of human error. Often casualties result from ignorance or disregard of common industry knowledge. Frequently, required or established operating procedures and/or maintenance and inspection criteria are overlooked or overruled. Why humans disregard, overlook, overrule, or ignore procedures is not sufficiently well understood.

Conclusion 2

Examination of the causal factors listed in Appendices D through F emphasizes further the influence of the human element in marine operations. Conversely, technologically related causal factors are seen to be far less significant. The committee's conclusion:

2. There is an inverse relationship between the known causes of maritime accidents and the areas in which research is conducted. Most major marine casualties are due to some form of human failing, whereas most maritime research resources are expended on hardware.

Conclusion 3

A surprising number of pertinent R&D projects in the marine field and in related fields, especially aerospace, have been completed, but their results remain unused or untried in service. For example, the committee felt that lack of radio discipline creates navigational hazards, especially on congested waterways. Yet radio traffic could be monitored by fitting inexpensive radio identifiers to all transmitters. The technology has been available for some time but has not been adopted. The committee concluded:

3. In the opinion of many committee members and of experts who met with the committee, considerable maritime research results, for many reasons, are not implemented operationally.

Conclusion 4

The lethargy in, or resistance to, implementing available developments as noted in Conclusion 3 leads logically to Conclusion 4 on the lack of follow-through. The National Aeronautics and Space Administration (NASA) conducts a very successful technology-transfer program that has been widely accepted by major industries. The use of satellites for discovering and monitoring natural resources, for communications, and for navigation and weather surveillance are but a few examples of the thousands of technology transfers from NASA R&D. The committee concluded:

4. The results of most research, not just maritime research, are published with little or no thought to "embedding" methodology--that is, arrangements for obtaining acceptance of the technological content and incorporating it into an operating system. Therefore, the technological content, however excellent, wastes away for lack of means of putting it to use.

Conclusion 5

The control of vessels is affected by many technical factors that are inadequately understood at present. For example, little quantitative knowledge exists for predicting bank-cushion and bank-suction effects in restricted waters, interaction forces between ships, and the effects of currents. Few maritime casualties today can

be attributed to inadequacies in these technologies, and research in these areas is funded at a very low level in the United States. However, the committee concluded:

5. Changes in vessel characteristics and in shipping patterns are beginning to press the state of the art in vessel-control technologies, such as hydrodynamics and communications. In the future, more advanced knowledge in these areas will be needed for the development of control systems and other hardware to help prevent collisions, rammings, and groundings.

Conclusion 6

In "The Impact of International Standards for Seafarers on Maritime Management," a study prepared in 1979, Cletus Joseph Walz at the University of Wales considered the adequacy of information on maritime casualties. He contends: "There is evidently no single compiler of information for all maritime casualties on a worldwide basis having complete data on the associated loss of life and property, damage to the environment, and cause of accidents." The committee concluded:

6. There are diverse maritime data bases, but no comprehensive marine-safety data base and no centralized method of reviewing the safety material in the various data bases.

Conclusion 7

The committee believes that public agencies and organizations, and others concerned about marine safety, have not recognized the operational distinctions between the growing offshore marine-support activities, inland-waterway activities, and ocean traffic. The tendency has been to consider ocean problems representative of all marine activities, but they are not. The operation of long river tows, for example, presents problems not common to ocean vessels. The committee felt that the distinctions should be recognized and concluded:

7. The U.S. maritime industry is diverse. It includes oceangoing ships, inland-waterway and Great Lakes operations, and offshore exploration and development. Each segment serves different needs and sectors of the economy; therefore standardized, national measures and policies that do not recognize this diversity will not produce the intended results.

The committee's recommendations flow from its conclusions, with emphasis on man-machine interfaces and research on technical problems that should reduce human error. The recommendations are directed to

the Coast Guard, the Maritime Administraton, and other interested public and private organizations.

Recommendation 1

There is no overall direction or program for maritime safety research in the United States; pieces of the problem are worked on, but many of the diverse efforts fail to be coordinated and implemented in the industry. The committee created a framework for guiding research by developing the function-flow block diagrams and problem lists. Therefore, the committee recommended:

1. Continuation and augmentation of the systematic methodology for determining causal factors established by the committee (Chapter IV) should be promoted to assure that maritime casualty research becomes balanced, holistic, and complete. The functional-flow block diagrams comprise a valuable foundation upon which to integrate such research.

Recommendations 2 and 3

Accident investigation determines how an accident occurs and states the probable cause or causes. However, the underlying cause, the "why" of an accident, when human failure is involved is seldom explored. Recommendations 2 and 3 address this basic problem:

2. Additional research should be funded to determine why the known causes of collisions, rammings, and groundings are ignored or overlooked and why operating rules and other procedures are overruled.

3. Research resources should be expanded for finding the root causes of human error in maritime casualties.

Recommendation 4

The committee found evidence of deficiencies in the man-machine interfaces needed to achieve optimum human performance. For example, one member of the committee, an experienced pilot of average height, deplored the need to stand on a box to see over the bridge enclosure of a recently built vessel. The committee recommended:

4. Additional research directed toward establishing industry guidelines for layout and display of control equipment for bridges and engine rooms should be funded. These standards must provide for improved man-machine interfaces for vessel control.

Recommendation 5

Among the many research projects already completed, many should be applicable to the prevention of collisions, rammings, and groundings. A method is needed for ensuring prompt implementation of research results where feasible. The recommendation:

5. Research on reducing maritime casualties should be encouraged to address both the technological content and the "embedding" methodology, i.e., the arrangements for obtaining acceptance of the technological content and incorporating it into an operating system.

Recommendation 6

Technological research should reduce maritime casualties not only through the development of technological improvements, *per se*, but also by their favorable influences on human behavior in reducing the probability of error. This led the committee to recommend:

6. Available technology to reduce human-factor causes of collisions, rammings, and groundings should be adopted, and research in the component technologies, such as hydrodynamics, control systems, and communications should be funded.

Recommendations 7 and 8

A central organization to define, coordinate, and stimulate research to reduce casualties while concurrently improving the efficiency and performance of equipment has operated with extraordinary efficiency in the aerospace field. This is evident from the success of NASA and its predecessor, the National Advisory Committee for Aeronautics, which began in 1917. The point is recognized in two recommendations:

7. An organization should be established to collect and maintain a data base on research applicable to marine safety and to maintain links with similar national and international data bases. This organization also should be responsible for disseminating research information affecting marine safety.

8. A committee should be established under the aegis of the Coast Guard to coordinate and review requirements and funds for research on reducing collisions, rammings, and groundings. The interagency Ship Structures Committee could serve as an organizational model.

Recommendation 9

Aviation safety has long benefited from free and cooperative exchange of accident-prevention information widely disseminated by publications and seminars. The philosophy is in accordance with Ralph Waldo Emerson's advice to learn from the mistakes of others, because you won't live long enough to make them all yourself. The recommendation:

9. A non-adversarial organization, similar to the Flight Safety Foundation and the NASA/FAA Aviation Safety Reporting System, should be established to collect and disseminate information on casualties, near-accidents, and operating practices.

Recommendation 10

Obsolete regulations are awkward to enforce, inhibit the introduction of new technology, provoke irritation, and induce inefficient operation. Therefore, the committee recommends:

10. A study of existing maritime laws and regulations should be conducted to determine if they are applicable and enforceable with respect to the total U.S. maritime environment. Results of this research would be used as the basis for recommendations for repeal or revision of obsolete or inappropriate laws and regulations.

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APPENDIX A

OCEAN VOYAGE TASK PROBLEMS

The following numbered entries correspond to the numbered blocks in Figure 3, the functional-flow block diagram for an ocean voyage.

1. RECEIVE VOYAGE INSTRUCTIONS

    Improper or incomplete instructions
    Unknown destination
    Management pressure for maintaining schedules
    Partial reception of instructions
    Failure to follow voyage instructions

2. PLAN VOYAGE

    Incomplete planning
    Indefinite destination
    Short crew
    Ship-cargo compatibility
    Inadequate information on destination characteristics
    Lack of tug assistance
    Non-use of proper pilotage
    Unavailable or wrong assessment of weather information
    Unqualified crew (professional, physical)

3. CHECK WEATHER FORECASTS

    Inadequate weather service information
    Incorrect weather service information
    Conflicting weather service information
    Distribution of weather information
    Inability to assess weather information
    Ignoring weather information

Lack of knowledge of ship response to varying weather conditions
Failure to consider ship response to weather

4. CALCULATE TIDE AND CURRENT

Inadequate real-time information
Other factors affecting tides (wind, storm, etc.)
Traffic congestion at high tide (only if all vessels proceed at same time)
Failure to calculate
Lack of knowledge of currents
Failure to measure specific gravity
Lack of knowledge of ship response to varying current and water depth
Failure to consider ship response to currents

5. SELECT CHARTS

Lack of international chart uniformity
Inaccurate charts
Error in updating chart
Inadequate distribution of updating material
Availability of charts
Private charts with selective distribution
Timely and complete distribution of updating material
Failure to properly use charts

6. REVIEW NOTICES TO MARINERS

Failure to review
Lack of postal service speed
Too much information

7. CORRECT CHARTS AND PUBLICATIONS

Failure to correct
Lack of postal service speed
Too much information
Error in making correction
Illegible corrections
Nature of the task (boring)
Off-station or destroyed aids to navigation

8. <u>LAY OUT INTENDED TRACK AND MARK NAVAIDS</u>

Not done
Error in plotting
No criteria for hazard avoidance
Deviating from track
No awareness of cross traffic
Inadequate identification of shallow areas
Not taking into account current set
No awareness of traffic volume

9.-13. <u>TEST OPERATION OF EQUIPMENT</u>

Failure to test
Failure to do adequate tests
Incorrect test and inspection
Misread test results
Disregard test results

14. <u>CHECK DRAFT</u>

Misread draft
Failure to read drafts
Inability to read draft marks
Miscalculate conversion from fresh to salt water
Failure to allow for dynamic effects
Failure to allow for weather conditions
Failure to allow for tide conditions
Failure to consider trim (speed-rudder response)

15. <u>CALCULATE STABILITY</u>

16. <u>INSURE ALL STORES AND FUEL ON BOARD</u>

17. <u>REVIEW STANDING ORDERS</u>

Orders not understandable
Instructions in language different than crew's
Mixed languages among crew
Orders inappropriate
Orders incomplete

18. INSURE ADEQUATE CREW ON BOARD

Lack of literacy
Failure to report
Sobriety or physical incapacity
Standards of manning and qualification
Failure to do task

19. NOTE WEATHER CONDITIONS

Failure to do task

20. TAKE ON PILOT

Insure competent pilotage available

21. BRIEF PILOT ON SHIP CONDITION

No requirement, legal or other, for briefing
Personal animosity
Pilot professional qualifications
Pilot physical qualifications

22. PILOT ASSUMES VESSEL CON

No formal rules or legal definition of pilot responsibility
Language differences between pilot and helmsman
Personal animosity

23. SURVEY AREA AROUND BERTH

Poor visibility from bridge due to design or cargo stowage
Poor atmospheric visibility
Preoccupation or inadequate survey
Failure to perform task
Misinterpret or ignore scene

24. SURVEY LOCAL TRAFFIC

Poor visibility from bridge due to design or cargo stowage or shoreside obstruction
Poor atmospheric visibility
Preoccupation or inadequate survey
Failure to perform task
Port configuration

Dock configuration
Misinterpret or ignore scene

25. <u>CONTACT LOCAL TRAFFIC AS REQUIRED</u>

Traffic may not respond
Traffic may not have radio
Interference from other radios
Failure to perform task
Confusion caused by multiple communications

26. <u>GIVE POSITION ORDERS TO TUGS</u>

Incorrect orders
Misinterpretation of orders
Inadequate mooring lines
Language problems
Inability to monitor foreign language orders
Pilot in foreign waters
Inadequate communications

27. <u>CONTACT VTS (IF AVAILABLE)</u>

Language problems
Inoperative radio
Lack of radio
Radio interference
Mistakes by VTS personnel
Failure to perform task

28. <u>DECLARE DEPARTURE INTENTION BY RADIO</u>

Covered by VTS where VTS installed
Not mandatory in all areas
Radio failure
Lack of radio
Radio interference
Failure to perform task

29. <u>CONTACT LINEHANDLERS TO PREPARE TO CAST OFF</u>

30. <u>NOTIFY VTS OF DEPARTURE (IF AVAILABLE)</u>

Lack of radio
Radio interference
Language problems
Inoperative radio
Failure to perform task

31. <u>SCAN AREA AROUND VESSEL</u>

(Same as No. 24)

32. <u>GIVE ORDERS TO CAST OFF</u>

Misinterpretation of order
Language problems
Wrong sequence of orders
Failure to perform task

33. <u>DIRECT TUGBOATS</u>

Tug breakdown
Tow line breakage
Failure to obey orders
Personal animosity
Anticipation of commands
Radio interference
Inoperative radio
Language problems
Insufficient tug power
Insufficient number of tugs
Inexperienced tug personnel

34. <u>MONITOR BRIDGE INDICATORS</u>

Equipment failures
Poor bridge design
Inattention
Failure to perform task
No standards for design and layout

35. <u>OBSERVE AND EVALUATE VESSEL RESPONSE TO ORDERS</u>

Failure to perform task
Unfamiliarity with vessel characterisitics

Improper performance of task
Misread response

36. GIVE NEW MANEUVERING ORDERS

Equipment failure (non-propulsion)
Language problems
Machinery failure (propulsion)
Improper order
Poor judgment
Tug failure
Tow wire failure
Communication problems (including language problems)

37. MAINTAIN ON-GOING MANEUVER

Poor judgment
Incorrect order
Failure to observe hazards
Failure to properly interpret vessel response

38. RELEASE TUGBOATS

Premature release
Failure to release
Pilot/master misunderstanding
Language problems
Communication problems with tugs

39. DIRECT VESSEL'S COURSE THROUGH CHANNEL

Failure to observe hazards
Failure to observe weather
Poor weather
Equipment and machinery failures
Lack of accurate positions
Failure to locate navigation aids
Deviation from channel
Operator overconfidence
Confusion and misinterpretation
Maneuvering ability of vessel
Difference in shiphandler abilities
Incorrect information passed to new watch
Failure to follow orders
Excessive speed
Unfamiliarity with vessel characteristics

Congested traffic
Off-station aids to navigation

40. EVALUATE VESSEL TRACK RELATIVE TO NAVIGATION AIDS AND FIXED OBJECTS

Equipment and machinery failure
Navigation aids missing or misplaced
Poor visibility from bridge
Failure of lighted or radio navigation aids
Poor judgment
Operator overconfidence
Poor weather

41.-42. ADJUST OR MAINTAIN COURSE AND SPEED

Equipment and machinery failure
Incorrect orders
Failure to observe course and speed
Unanticipated response
Misjudgment of response
Failure to perform task

43. COMMUNICATE WITH VESSELS IN VICINITY

Failure to signal
Radio interference
Lack of radio
Inoperative radio
Failure to hear or see other vessel
Improper signal
Misinterpretation of signals
Giving one signal and doing something else

44. MONITOR BRIDGE INDICATORS AND RADIO

Equipment failure
Sensory overload
Poor bridge design
Failure to perform task
Distraction from more important duties

45. MAINTAIN VESSEL'S LOG

Distracting to crew

46. <u>CONTACT VTS FOR TRAFFIC ADVISORY (IF AVAILABLE)</u>

VTS personnel error
Lack of standard VTS system
Nonuniform requirements
Failure to perform task
Radio interference
Inoperative radio
Lack of radio

47. <u>EVALUATE HAZARD FROM OTHER TRAFFIC</u>

Failure to assess course, speed, and intentions
Failure to see lights
Failure to hear signals
Intoxication
Fatigue
Inattention
Distractions or sensory overload
Poor judgment
Equipment failure
Failure to perform task
Communications problems
Faulty assumptions
Misinterpretation of intentions
Unfamiliarity with vessel characteristics
Unfamiliarity with waterway configuration

48. <u>TAKE EVASIVE ACTION</u>

Insufficient action, not positive
Action taken too late
Violation of rules of the road
Failure to indicate intentions
Poor judgment
Unfamiliarity with vessel characteristics

49. <u>MAINTAIN COURSE AND SPEED</u>

Improper action

50. <u>CLEAR CHANNEL</u>

Improperly located navaids
Missing navaids
Inattention

Overconfidence
Failure to note changes in procedures or rules of the road

51. RELEASE PILOT AND ASSUME CON

Master unfamiliar with area configuration
Master unfamiliar with local procedures

52. INCREASE SPEED TO VOYAGE SPEED

Poor visibility
Heavy weather
Poor judgment, excessive speed
Company pressure to meet schedule

53. SET COURSE FOR DESTINATION

Set wrong course
Failure to determine position
Navigation equipment failure
Indefinite destination
Establish and apply gyro error
Failure to maintain proper navigation watch
Poorly qualified personnel assigned to navigation watch

54. NOTE DEPARTURE IN LOG

Distraction from more important duties

55. TRANSMIT DEPARTURE DATA (IF REQUIRED)

56. DETERMINE VESSEL'S POSITION

Equipment failure
Poor visibility
Nonuniform licensing requirments
Failure to perform task
Management policies
Poor training

57. <u>MAINTAIN PLOT OF VESSEL'S POSITION</u>

Failure to perform task
Error in marking chart
Error in determining position

58. <u>MAINTAIN VESSEL'S LOG</u>

Distraction from more important duties

59.-60. <u>PLOT AND EVALUATE HAZARDS</u>

(Same as No. 47)

61. <u>MAINTAIN COURSE AND SPEED</u>

(Same as No. 49)

62. <u>TAKE EVASIVE ACTION</u>

(Same as No. 48)

63. <u>MONITOR BRIDGE INDICATORS</u>

(Same as No. 44)

64. <u>MONITOR BRIDGE PERSONNEL</u>

Poor training

65. <u>MONITOR WEATHER</u>

Failure to perform task

66. <u>REVIEW NOTICES TO MARINERS</u>

No postal service at sea
Failure to correct charts or publication

67.-68. APPROACH CHANNEL ENTRANCE, PICK UP PILOT

Converging traffic
Poor visibility
Rough weather
Equipment failure
Poor judgment
Unfamiliarity with local procedures
Unfamiliarity with area configuration

69. BRIEF PILOT ON SHIP CONDITION

(Same as No. 21)

70. PILOT ASSUMES VESSEL CON

(Same as No. 22)

71. ENTER CHANNEL

Converging traffic

72. REDUCE SPEED TO CHANNEL TRANSIT SPEED

Failure to reduce speed

73. NOTIFY VTS OF ARRIVAL

(Same as No. 27)

74. NOTE ARRIVAL IN LOG

(Same as No. 54)

75.-85. HARBOR TRANSIT

(Same as No. 39-49)

86. MEET TUGBOATS

Assure proper tugs available

87. <u>GIVE POSITION ORDER TO TUGBOATS</u>

(Same as No. 26)

88.-89. <u>SURVEY AND CONTACT LOCAL TRAFFIC</u>

(Same as No. 24-25)

90. <u>DIRECT TUGBOATS</u>

(Same as No. 33)

91. <u>APPROACH BERTH</u>

Poor atmospheric visibility
Poor visibility from bridge due to design or cargo
Dock configuration
Harbor configuration
Use of excessive speed

92. <u>SURVEY AREA AROUND BERTH</u>

(Same as No. 23)

93. <u>CONTACT VTS</u>

(Same as No. 27)

94.-96. <u>OBSERVE AND EVALUATE VESSEL RESPONSE</u>

(Same as No. 35-37)

97. <u>CONTACT LINEHANDLERS</u>

(Same as No. 29)

98. <u>POSITION VESSEL AT BERTH</u>

Dock configuration
Unknown currents
Insufficient number of tugboats

Insufficient tug horsepower
Poor judgment

99. <u>ORDER MOORING LINES OVER THE SIDE</u>

Broken line
Poor communication
Inexperienced deck crew
Inexperienced dockside linehandlers

100. <u>NOTIFY VTS OF DOCKING</u>

(Same as No. 30)

101. <u>LOG DOCKING</u>

(Same as No. 54)

102. <u>NOTIFY ENGINE ROOM FINISHED WITH ENGINES</u>

Inadvertent engine order after bridge watch secured

APPENDIX B

RIVER TOWBOAT VOYAGE TASK PROBLEMS

The following numbered entries correspond to the numbered blocks in Figure 4, the functional-flow block diagram for a river towboat voyage.

1. RECEIVE VOYAGE INSTRUCTIONS

   Improper instructions
   Inadequate or incomplete instructions
   Partial instructions
   Instructions misunderstood
   Voyage improperly planned

2. REVIEW TOW LAYOUT

   Failure to review tow layout
   Inattention to tow layout
   Inadequate experience in proper tow layout

3. EVALUATE HAZARDS OF TOW MAKEUP

   Insufficient information on barge contents
   Inadequate knowledge of barge hull condition
   Inattention to specially required handling procedures
   Lack of knowledge of individual barge configuration

4. ACCEPT TOW LAYOUT

   Same as number 3)

5. REJECT TOW LAYOUT

(Same as number 3)

6. REVISE TOW LAYOUT

(Same as number 3)

7. SUPERVISE MAKEUP OF TOW

Inattention to tow makeup
Worn or understrength wire lashings
Improperly installed interbarge connections
Insufficient supply of proper lashing material

8. CHECK BARGES FOR LEAKS, DAMAGE, AND SAFETY HAZARDS

Inadequate check of barges
Incomplete inspection
Lack of knowledge for proper check

9. DIRECT FLEET BOAT

Inadequate communications
Misunderstood directions
Poorly maintained fleet boat
Poorly operated fleet boat
Underpowered fleet boat

10. SURVEY LOCAL TRAFFIC

Poor visibility (design or cargo stowage)
Poor visibility (atmospherics)
Incomplete survey

11. CONTACT LOCAL TRAFFIC AS REQUIRED

Poor radio transmission or reception (atmospheric)
Poor radio transmission or reception (equipment)
Poor radio transmission or reception (operator procedure)
Failure of other traffic to respond
Interference by other radios

12. <u>CHECK RIVER CONDITIONS</u>

Improper reports received
Unfamiliarity with local river configuration

13. <u>CONFIRM ENGINE OPERATION</u>

Failure to test
Acceptance of less than peak performance

14. <u>CONTACT VTS</u>

Inoperative radio transmitter
Failure of system
Interference by other radios
Improper procedure

15. <u>SURVEY AREA AROUND FACILITY</u>

Poor visibility (design or cargo stowage)
Poor visibility (atmospherics)
Failure to perform task
Misinterpretation of available information

16. <u>DECLARE DEPARTURE INTENTION BY RADIO</u>

Failure to make call
Failure of other vessels to monitor radio

17. <u>ORDER CREW TO CAST OFF</u>

Improper orders
Misinterpretation of orders

18. <u>NOTIFY VTS OF DEPARTURE</u>

Inoperative radio transmitter
Failure of system
Interference by other radios
Improper procedure

19. <u>SCAN AREA AROUND VESSEL</u>

Poor visibility (design or cargo stowage)
Poor visibility (atmospheric)
Failure to perform task
Misinterpretation
Incomplete survey of area

20. <u>NOTE DEPARTURE IN LOG</u>

Distraction from more important duties

21. <u>MONITOR BRIDGE INDICATORS</u>

Confusion caused by multiple communications

22. <u>MANEUVER TOW AWAY FROM FACILITY</u>

Engine failure
Steering failure
Control failure
Miscalulation of effect of current
Miscalculation of depth of water

23. <u>*OBSERVE AND EVALUATE VESSEL RESPONSE*</u>

Unfamiliarity with vessel
Unanticipated response
Machinery failures

24. <u>ADJUST TOW CONFIGURATION, LASHINGS, AND/OR ENGINES</u>

Failure of interbarge lashings
Failure to regularly inspect lashings
Improper placement of barges in tow

25. <u>MAINTAIN MANEUVERS</u>

Improper order
Failure to observe hazards

26. MONITOR INDICATORS

Distraction from maneuvering
Improper indicator readings

27. MONITOR WEATHER

Failure to perform task

28. COMMUNICATE WITH OTHER RIVER TRAFFIC

Radio inoperative
Failure of other vessels to respond
Failure to perform task

29. MAINTAIN VESSEL'S LOG

Distraction from other duties

30. EVALUATE HAZARDS FROM OTHER TRAFFIC

Course and speed of other vessels
Inoperative navigation lights of other vessels
Other vessels out of control
Failure to hear whistle signals
Fatigue
Intoxication
Closed pilothouse doors
Failure to take timely action
Judgment failure
Faulty assumptions
Misinterpretation of other vessel's actions
Unfamiliarity with own vessel's characteristics

31. EVALUATE HAZARDS FROM FIXED OBSTRUCTIONS

Inattention to navigation duties
Unfamiliarity with operating area

32. <u>TAKE EVASIVE ACTION</u>

Insufficent action
Action taken too late
Improper action

33. <u>MAINTAIN COURSE AND SPEED</u>

Improper order
Failure to observe hazards

34. <u>APPROACH DESTINATION</u>

Failure to observe hazards
Machinery failure

35. <u>ADJUST SPEED FOR SAFE DOCKING</u>

Use of excessive speed
Insufficiently applied power
Failure to stop headway early enough

36. <u>MANEUVER FOR DOCK POSITION</u>

Failure to plan maneuver
Miscalculation of wind and current
Loss of engines
Steering failure

37. <u>NOTIFY VTS OF DOCKING INTENTION</u>

Radio failure
Failure to perform task
Improper information transmitted

38. <u>MOOR TOW IN FACILITY</u>

Improper mooring
Understrength lines

39. <u>NOTE ARRIVAL IN LOG</u>

APPENDIX C

GREAT LAKES VOYAGE TASK PROBLEMS

The following numbered entries correspond to the numbered blocks in Figure 5, the functional-flow block diagram for a Great Lakes voyage from the lower to upper Lakes.

1. <u>RECEIVE VOYAGE INSTRUCTIONS EX DISPATCHER</u>

   Improper or incomplete instructions
   Indefinite destination
   Management pressure to proceed
   Inattention to voyage instructions

2. <u>PLAN VOYAGE</u>

   Incomplete planning
   Indefinite destination
   Short crew
   Inadequate or unavailable reference material, i.e., charts and sailing directions, etc.
   Failure to determine necessity of tug assistance

3. <u>LOAD CARGO OR BALLAST</u>

   Making contact with cargo loading equipment
   Failure to follow loading manual
   Failure to prepare cargo holds for loading or ballast tanks for ballasting
   Taking the ground at loading berth
   Failure of crew to follow First Mate's instructions during loading

4. CHECK WEATHER AND ICE FORECASTS

Failure to check
Inadequate check of advisory sources, i.e., NOAA and USCG
Inaccurate weather information
Conflicting weather information
Inability to assess weather information
Ignoring weather information

5. ORDER TUG ASSISTANCE

Ordering improper number and/or size of tugs

6.-10. TEST OPERATION OF EQUIPMENT

Failure to test
Failure to test adequately
Incorrect tests and/or inspections
Misinterpreted test results
Erroneous test results

11. CHECK DRAFTS

Failure to read drafts
Inability to read drafts
Misread drafts
Failure to allow for dynamic effects

12. SECURE CARGO HATCHES

Lack of firm management policy on securing cargo hatches prior to departure from loading berth
Failure to secure hatches because of fair weather
Failure to secure hatches because of inoperative clamps
Failure to instruct deck hands to secure hatches
Improper supervision during hatch securing
Failure of crew to follow orders
Distorted hatch covers and/or coamings
Worn or missing cargo hatch gaskets

13. INSURE ALL CREW ABOARD

Improper manning standards
Unavailability of qualified crew
Failure to report
Sobriety or physical incapacity

Failure to determine proper crew aboard
Failure to report crew shortage to management

14. INSURE ALL STORES AND FUEL ON BOARD

Failure to do so
Improper assessment of stores and fuel on board
Inadequate provision because of management policies
Contamination of stores and fuel on board

15. SELECT CHARTS AND REVIEW LCA TRACKS

Inadequate or unavailable charts because of planning deficiency
Inaccurate charts
Failure to select proper charts

16. NOTE LOCAL WEATHER CONDITIONS

Failure to do task
Management failure to supply ship with necessary meteorological equipment
Failure of onboard meteorological equipment

17. REVIEW NOTICES TO MARINERS

Nonreceipt of current notices
Failure to review
Overlooked data because of excessive information

18. CORRECT CHARTS AND PUBLICATIONS

Failure to correct
Erroneous corrections
Illegible corrections
Lack of diligence to task

19. SURVEY BERTH AREA

Failure to perform task
Poor visibility because of bridge design
Poor atmospheric visibility
Cursory survey

Misinterpret or ignore scene
Dock configuration hinders thorough survey

20. CHECK LOCAL HARBOR/RIVER TRAFFIC VIA RADIO

Failure to perform task
Failure of radio
Radio interference
Lack of response

21. HOOK UP ASSISTING TUGS

Incorrect positioning orders to tugs
Improper connection of tugs to vessel
Misinterpretation of order by tug crew
Failure of tug crew to respond to orders
Failure of radio
Radio interference

22. LAND CREW FOR LINEHANDLING

Landing inadequate number of linehandlers
Landing incapable linehandlers
Failure of landing boom equipment

23. ISSUE ENGINE ROOM ORDERS

Failure to perform task
Issue incorrect orders
Misinterpretation or orders
Malfunctions of telegraph or telephone systems between bridge and engine room

24. SURVEY HARBOR/RIVER AREA

(Same as No. 19) plus
Failure to establish and maintain proper lookout

25. CONTACT USCG VIA RADIO FOR SAFETY CALL UPON DEPARTURE FROM BERTH

(Same as No. 20)

26. WHISTLE OR RADIO SIGNALS TO DIRECT TUGS

(Same as No. 20) plus
Improper orders or signals
Misinterpretation of orders or signals
Failure of tug crew to respond

27. SIGNAL LINEHANDLERS TO CAST OFF

Failure to do so
Improper signals
Failure of whistle
Failure to comply with signals
Improper response

28. MONITOR BRIDGE INDICATORS

Failure to perform task
Inattention
Poor bridge layout
Equipment failures
Misinterpretation of indicators
Sensory overload

29. REBOARD LINEHANDLERS

Diversion of attention of bridge watch
Navigation imperiled during reboarding

30. OBSERVE AND EVALUATE VESSEL REPONSE TO TUGS AND ENGINE

Failure to perform task
Improper performance of task
Unfamiliarity with vessel's navigating characterisitcs
Unfamiliarity with harbor characteristics
Inadequate evaluation

31. GIVE NEW MANEUVERING ORDERS

Incorrect choice of order
Improper issuance of order
Misinterpretation of order by tugs or engine room
Lack of response by tugs or engine room
Equipment failure, navigation and communication
Machinery failure, steering and propulsion machinery

Tow hawser failure
Tug failure

32. MAINTAIN ON-GOING MANEUVER

Errors in judgment
Failure to observe hazards

33. RELEASE ASSISTING TUGS

Failure to release
Premature release
Plus Nos. 20 and 26

34. DIRECT VESSEL'S COURSE

Failure to observe hazards to navigation
Failure to observe weather and ice conditions
Adverse weather and ice conditions
Equipment and machinery failures
Failure to determine position accurately
Missing or mislocated navigation aids
Crew incapacities (fatigue, inattention, distraction, confusion, sensory overload, intoxication, physical limitations, poor training)
Errors in judgment (faulty assumptions, misinterpretations, overconfidence)
Failure to establish and maintain proper lookout
Incapable helmsmanship
Deviation from channel
Unfamiliarity with vessel's navigating characteristics and channel characteristics
Differences in ship handling ability
Excessive speed
Inadequate speed
Poor visibility from bridge
Failure to follow orders
Failure to issue correct orders
Incorrect information passed to new watch

35. SIGNAL VESSELS IN VICINITY

(Same as No. 20) plus
Improper signal

Failure to see or hear other vessel
Misinterpretation of signals

36. MONITOR BRIDGE INDICATORS AND RADIO

(Same as No. 28) plus
Failure of radio
Radio interference
Excessive radio traffic

37. MAINTAIN VESSEL'S LOG

Lack of firm management policy
Lack of due diligence by crew
Inaccurate entries

38. REPORT VESSEL'S DEPARTURE AND POSITION VIA LORAN RADIO

Failure to report
Failure of radio
Radio interference
Inaccurate report

39. EVALUATE TRAFFIC HAZARDS

Failure to assess courses, speed, and intentions of other vessels
Failure to observe traffic hazards because of:
- --Adverse weather
- --Poor bridge visibility
- --Equipment failure
- --Crew incapacities (fatigue, inattention, distraction, confusion, sensory overload, intoxication, physical limitations, poor training)

Errors in judgment (faulty assumptions, misinterpretations, overconfidence)
Unfamiliarity with vessel's navigating characteristics and channel characteristics
Failure of communication with other vessels

40. <u>EVALUATE VESSEL TRACK RELATIVE TO NAVIGATION AIDS AND FIXED OBJECTS</u>

Equipment and machinery malfunctions
Navigation aids missing or mislocated
Poor visibility from bridge
Failure of navigational aid signals
Operator overconfidence
Crew incapacities

41. <u>MAINTAIN COURSE AND SPEED</u>

(Same as No. 32)

42. <u>TAKE EVASIVE ACTION</u>

Errors in judgment
Incorrect choice of order:
--Insufficient action
--Action taken too late
--Action violating Rules of the Road
--Unfamiliarity with vessel's navigation characteristics
Improper issuance of order
Misinterpretation of order
Equipment and machinery failures
Failure to communicate intentions to other vessels

43. <u>ADJUST COURSE AND SPEED</u>

Errors in judgment
Unfamiliarity with vessel's navigation characteristics
Incorrect choice of order
Improper issuance of order
Misinterpretation of order
Lack of response to order
Equipment and machinery failures

44. <u>MAINTAIN COURSE AND SPEED</u>

(Same as No. 32)

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RESEARCH NEEDS TO REDUCE MARITIME COLLISIONS, RAMMINGS, AND GRO--ETC(U)
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45. <u>CLEAR CHANNEL</u>

(Same as No. 34)

46. <u>ATTAIN VOYAGE SPEED</u>

Errors in judgment--excessive speed
Inadequate evaluation of weather and ice conditions
Communicate incorrect orders to engine room
Failure to assess traffic hazards

47. <u>SET COURSE PER LCA TRACK</u>

Set wrong course
Failure to determine position accurately
Failure of navigation equipment

48. <u>MAINTAIN LOGS</u>

(Same as No. 37)

49. <u>DETERMINE VESSEL'S POSITION</u>

Failure to perform task
Limitations of ability for crew
Equipment failure
Lack of adequate navigation equipment because of management policy

50. <u>MAINTAIN PLOT OF VESSEL'S POSITION</u>

(Same as No. 37)

51. <u>REPORT VESSEL'S POSITION VIA LORAN RADIO</u>

(Same as No. 38)

52. <u>PLOT AND EVALUATE TRAFFIC HAZARDS</u>

(Same as No. 39)

53. PLOT AND EVALUATE NAVIGATION HAZARDS

(Same as No. 40)

54. MONITOR BRIDGE INDICATORS

(Same as No. 28)

55. MONITOR BRIDGE PERSONNEL

Lack of firm management policy
Inadequate organization of bridge team
Inadequate supervision by watch commander
(inattention to crew incapacities)
Inadequate training

56. MONITOR WEATHER AND ICE CONDITIONS

(Same as Nos. 4 and 16)

57. MAINTAIN COURSE AND SPEED

(Same as No. 32)

58. TAKE EVASIVE ACTION

(Same as No. 42)

59. APPROACH DETROIT RIVER CHANNEL

Failure to establish ship's position
Failure to evaluate traffic hazards, including
upbound, downbound, and cross-bound vessel
traffic
Failure to evaluate hazards to navigation
Missing, mislocated, or inoperative navigation aids
Deviation from channel
Excessive speed
Poor visibility from bridge
Incapable helmsmanship
Differences in shiphandling ability
Equipment and machinery failures

60. ENTER DETROIT RIVER

(Same as No. 59)

61. REDUCE SPEED

Failure to do so
Equipment and/or machinery failure

62. NOTIFY COAST GUARD OF POSITION AND DIRECTION

(Same as No. 20)

63. NOTE POSITION IN LOG

(Same as No. 37)

64. TRANSMIT SAFETY CALL VIA VHF-FM

(Same as No. 38)

65. DIRECT VESSEL'S COURSE THROUGH RIVER

(Same as No. 34)

66. SIGNAL VESSELS IN VICINITY

(Same as No. 53)

67. MONITOR RADIO AND BRIDGE INDICATORS

(Same as No. 36)

68. EVALUATE HAZARDS FROM OTHER VESSEL TRAFFIC

(Same as No. 39)

69. EVALUATE VESSEL TRACK RE NAVIGATION AIDS AND FIXED OBJECTS

(Same as No. 40)

70. <u>ADJUST COURSE AND SPEED</u>

(Same as No. 43)

71. <u>MAINTAIN COURSE AND SPEED</u>

(Same as No. 44)

72. <u>MAINTAIN COURSE AND SPEED</u>

(Same as No. 32)

73. <u>ADJUST COURSE AND SPEED</u>

(Same as No. 42)

74. <u>CLEAR CHANNEL</u>

(Same as No. 45)

75. <u>ATTAIN VOYAGE SPEED</u>

(Same as No. 46)

76. <u>SET COURSE PER LCA TRACK</u>

(Same as No. 47)

77. <u>MAINTAIN LOGS</u>

(Same as No. 37)

78. <u>DETERMINE VESSEL'S POSITION</u>

(Same as No. 49)

79. <u>MAINTAIN PLOT OF POSITION</u>

(Same as No. 37)

80. <u>REPORT POSITION VIA LORAN RADIO</u>

(Same as No. 38)

81. <u>PLOT AND EVALUATE TRAFFIC HAZARDS</u>

(Same as No. 39)

82. <u>PLOT AND EVALUATE NAVIGATION HAZARDS</u>

(Same as No. 40)

83. <u>MONITOR BRIDGE INDICATORS AND RADIO</u>

(Same as No. 36)

84. <u>MONITOR BRIDGE PERSONNEL</u>

(Same as No. 55)

85. <u>MONITOR WEATHER AND ICE CONDITIONS</u>

(Same as Nos. 4 and 16)

86. <u>MAINTAIN COURSE AND SPEED</u>

(Same as No. 32)

87. <u>TAKE EVASIVE ACTION</u>

(Same as No. 42)

88. <u>APPROACH ST. MARY'S RIVER CHANNEL</u>

(Same as No. 59)

89. <u>ENTER ST. MARY'S RIVER</u>

(Same as No. 59)

90. REDUCE SPEED

(Same as No. 61)

91. NOTIFY COAST GUARD OF POSITION AND DIRECTION

(Same as No. 20)

92. NOTE POSITION IN LOG

(Same as No. 37)

93. TRANSMIT SAFETY CALL VIA VHF-FM

(Same as No. 38)

94. CONTACT CORPS OF ENGINEERS FOR LOCKING SCHEDULE AND INSTRUCTIONS

(Same as No. 20.)

95. MONITOR FOG, WIND, AND ICE REPORTS

(Same as Nos. 4 and 16)

96. RECEIVE TRAFFIC AND/OR ANCHORING INSTRUCTIONS FROM COAST GUARD

(Same as No. 20)

97. PROCEED TO DESIGNATED ANCHORAGE

Failure to check speed
Unfamiliarity with vessel's handling characterisitics
Errors in shiphandling
Incapable helmsmanship
Failure to prepare anchor(s) for dropping
Failure to evaluate accurately nearby vessel traffic tracks and positions of anchored vessels
Adverse weather conditions
Failure to communicate intentions to nearby vessel traffic
Inadequate maneuvering speed
Failures of equipment and machinery
Errors in navigative judgment

Incorrect orders to deck and engine departments
Misinterpretation of orders by crew
Lack of response to orders by crew
Poor visibility from bridge
Failure to establish and maintain a proper lookout

98. ANCHOR

Excessive speed
Errors in navigation judgment
Failures of equipment and machinery
Incorrect order to crew
Misinterpretation of orders by crew
Lack of response by crew
Errors in shiphandling
Failure to mount anchor watch
Failure to display anchor signals

99. PROCEED TOWARD DESIGNATED LOCK

Inattention to downbound vessel traffic
Inattention to navigation aids, including locking signal lights
Inadequate shiphandling in lock approach area
Unfamiliarity with vessel's handling characteristics
Excessive speed
Inadequate maneuvering speed
Incapable helmsmanship
Failure to attend stern anchor
Adverse weather conditions
Failure to establish and maintain communication with lock master
Failure to heed lock master's instructions
Failure of equipment and machinery
Incorrect order to crew
Misinterpretation of orders by crew
Lack of response to order by crew
Poor visibility from bridge
Failure to maintain proper lookout

100. REDUCE SPEED

(Same as No. 61)

101. LAND LINEHANDLERS

(Same as No. 22) plus
Failure to issue proper orders to linehandlers
Misinterpretation of orders by linehandlers
Lack of response by linehandlers
Failure of mooring winches and controls
Failure of mooring wires
Failure of bollards on approach wall

102. ENTER LOCK

Inadequate pre-locking moor (wires and fenders)
Failure to maintain communications with lock master
Failure to heed instructions of lock master
Failure to issue correct orders to crew including linehandlers
Misinterpretation of orders by crew including linehandlers
Inadequate ship handling capability
Excessive speed
Failures of equipment and machinery

103. MOOR IN LOCK

Failure to heed lock master's instructions
Failure to issue correct orders to linehandlers
Misinterpretation of orders by linehandlers
Lack of response by linehandlers
Inadequate lock moor (wires and fenders)
Failures of equipment and machinery, including mooring winches and controls
Failure of mooring wires

104. UNMOOR FROM LOCK

Failure to issue correct orders
Misinterpretation of orders by linehandlers
Lack of response by linehandlers
Failures of equipment and machinery, including mooring winches and controls
Failure of mooring wires

105. REBOARD LINEHANDLERS

Diversion of attention of bridge watch

106. EXIT LOCK

Failure to issue correct orders to crew
Misinterpretation of orders by crew
Lack of response by crew
Inadequate shiphandling capability
Excessive speed
Failure of equipment and machinery

107. TRANSMIT SAFETY CALL VIA RADIO

(Same as No. 38)

108. DIRECT VESSEL'S COURSE THROUGH RIVER

(Same as No. 3)

109. SIGNAL VESSELS IN VICINITY

(Same as No. 35)

110. MONITOR RADIO AND BRIDGE INDICATORS

(Same as No. 36)

111. EVALUATE HAZARD FROM OTHER VESSEL TRAFFIC

(Same as No. 36)

112. EVALUATE VESSEL TRACK RELATIVE TO NAVIGATION AIDS AND FIXED OBJECTS

(Same as No. 40)

113. <u>MAINTAIN COURSE AND SPEED</u>

(Same as No. 32)

114. <u>ADJUST COURSE AND SPEED</u>

(Same as No. 43)

115. <u>MAINTAIN COURSE AND SPEED</u>

(Same as No. 32)

116. <u>TAKE EVASIVE ACTION</u>

(Same as No. 42)

117. <u>CLEAR GROS CAP, ONTARIO</u>

(Same as No. 34)

118. <u>DETERMINE VESSEL'S POSITION</u>

(Same as No. 49)

119. <u>MAINTAIN LOGS</u>

(Same as No. 37)

120. <u>REPORT VESSEL'S POSITION VIA LORAN RADIO</u>

(Same as No. 37)

121. <u>MONITOR ICE AND WEATHER CONDITIONS</u>

(Same as Nos. 4 and 16)

122. <u>ATTAIN VOYAGE SPEED</u>

(Same as No. 46)

123. <u>SET COURSE PER LCA TRACK</u>

(Same as No. 47)

124. <u>MONITOR BRIDGE INDICATORS</u>

(Same as No. 28)

125. <u>MONITOR BRIDGE PERSONNEL</u>

(Same as No. 55)

126. <u>PLOT AND EVALUATE TRAFFIC HAZARDS</u>

(Same as No. 39)

127. <u>PLOT AND EVALUATE NAVIGATION HAZARDS</u>

(Same as No. 40)

128. <u>MAINTAIN COURSE AND SPEED</u>

(Same as No. 32)

129. <u>TAKE EVASIVE ACTION</u>

(Same as No. 42)

130. <u>NOTIFY SHIP'S AGENT OF ESTIMATED ARRIVAL</u>

(Same as No. 38)

131. <u>ORDER TUG ASSISTANCE AT DESTINATION</u>

Failure to order tugs
Ordering improper number and size of tugs

132. <u>RECEIVE ORDERS FOR LOADING</u>

Misunderstand orders

133. <u>RECEIVE ORDERS TO ANCHOR</u>

(Same as No. 20) plus
Misunderstand orders

134. <u>APPROACH LAKEHEAD PORT</u>

(Same as No. 59)

135. <u>ENTER LAKEHEAD PORT</u>

(Same as No. 59)

136. <u>REDUCE SPEED</u>

(Same as No. 61)

137. <u>NOTIFY COAST GUARD</u>

(Same as No. 20)

138. <u>MAINTAIN LOG</u>

(Same as No. 37)

139. <u>TRANSMIT SAFETY CALL VIA VHF-FM</u>

(Same as No. 38)

140. <u>RENDEZVOUS WITH TUGS</u>

Excessive speed
Inadequate shiphandling capability
Improper communication with tugs

141. <u>HOOK UP TUG ASSISTANCE</u>

(Same as No. 21)

142. <u>SURVEY HARBOR AREA</u>

(Same as No. 19)

143. <u>WHISTLE OR RADIO SIGNALS TO TUGS</u>

(Same as No. 26)

144. <u>ENGINE ROOM ORDERS</u>

(Same as No. 23)

145. <u>MONITOR BRIDGE INDICATORS AND RADIO</u>

(Same as No. 28)

146. <u>SURVEY LOCAL VESSEL TRAFFIC</u>

(Same as No. 19)

147. <u>OBSERVE AND EVALUATE VESSEL RESPONSE TO TUGS AND ENGINE</u>

(Same as No. 30)

148. <u>GIVE NEW MANEUVERING ORDERS</u>

(Same as No. 31)

149. <u>MAINTAIN ON-GOING MANEUVER</u>

(Same as No. 32)

150. <u>APPROACH BERTH</u>

Unfamiliarity with vessel's navigating characteristics
Unfamiliarity with harbor characteristics (e.g., currents)
Failure to observe and/or properly assess hazards of berth area
Ignoring hazards of berth area
Poor atmospheric visibility
Poor visibility because of bridge design
Inclement weather and/or ice conditions

- Inadequate evaluation of berthing plan
- Failure to establish and maintain a proper lookout
- Excessive or inadequate speed
- Incorrect positioning of tugs
- Improper connection of tugs to vessel
- Improper orders or signals to tugs, helmsmen, engine room
- Misinterpretation of orders or signals by tugs, helmsmen, engine room
- Lack of response by tugs, helmsmen, engine room
- Malfunction of communication equipment between bridge and tugs or engine room
- Crew incapacities (fatigue, inattention, distraction, confusion, sensory overload, intoxication, physical limitations, poor training)
- Errors in judgment (faulty assumptions, misinterpretation, overconfidence)
- Machinery failure, steering and propelling

151. <u>INSTRUCT LINEHANDLERS TO PREPARE TO LAND VIA BOOM</u>

(Same as No. 22)

152. <u>OPEN HATCHES</u>

Distractions to approach procedures

153. <u>POSITION VESSEL AT BERTH</u>

(Same as No. 150)
Inadequate water depth

154. <u>LAND LINEHANDLERS (CREW)</u>

(Same as No. 22)

155. <u>MOORING LINES OUT</u>

- Failure to issue correct orders to linehandlers
- Misinterpretation of orders by linehandlers
- Lack of response by linehandlers
- Failure of mooring wires or other equipment and machinery

156. <u>RELEASE TUGS</u>

Premature release

157. <u>REBOARD LINEHANDLERS</u>

(Same as No. 29)

158. <u>NOTIFY COAST GUARD OF DOCKING</u>

(Same as No. 20)

159. <u>LOG DOCKING</u>

(Same as No. 37)

160. <u>NOTIFY ENGINE ROOM FINISHED WITH ENGINES</u>

Failure to notify

APPENDIX D

OCEAN VOYAGE CAUSAL FACTOR CATEGORIES

In this composite list, each casualty causal factor is followed by the block numbers in Figure 3 in which the factor could lead to a collision, ramming, or grounding, based on the collective experience of the committee.

FAILURE TO DO TASK

1, 2, 3, 4, 5, 6, 7, 9-13, 14, 15, 16, 18, 19, 21, 23, 24, 25, 27, 28, 30, 31, 32, 34, 35, 41-42, 43, 44, 46, 47, 56, 59-60, 63, 65, 66, 69, 72, 73, 88-89, 92, 93 94, 100, 102

FAILURE TO CORRECTLY PERFORM TASK

2, 3, 4, 8, 9-13, 14, 15, 16, 23, 24, 26, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41-42, 43, 44, 37, 48, 50, 53, 56, 57, 59-60, 62, 63, 67-68, 87, 88, 90, 91, 92 94-96, 98, 102

LACK OF KNOWLEDGE/TRAINING

2, 3, 8, 18, 20, 21, 26, 29, 33, 35, 36, 37, 39, 40, 47, 48, 49, 51, 53, 56, 59-60, 61, 62, 64, 67-68, 69, 87, 90, 94-96, 97, 98, 99

ENVIRONMENTAL FACTORS

3, 4, 14, 23, 24, 31, 33, 39, 40, 47, 52, 59-60, 67-68, 88, 90, 91, 92

INCOMPLETE/INCORRECT INFORMATION

1, 2, 3, 4, 5, 8, 17, 21, 36, 37, 39, 40, 46, 47, 50, 59-60, 69, 95, 96, 98

LANGUAGE/LITERACY PROBLEMS

17, 18, 21, 22, 26, 27, 29, 30, 32, 33, 36, 38, 69, 70, 73, 87, 90, 93, 95, 97, 98, 99, 100

SOCIAL PROBLEMS

7, 18, 21, 22, 33, 38, 45, 47, 59-60, 69, 70, 90

EQUIPMENT PROBLEMS

2, 5, 9-13, 14, 23, 24, 25, 26, 27, 28, 30, 31, 33, 34, 36, 38, 39, 40, 41-42, 43, 44, 46, 47, 53, 56, 59-60, 63, 67, 68, 73, 87, 88-89, 90, 91, 92, 93, 95, 98, 99, 100

MANAGEMENT

1, 2, 8, 17, 18, 20, 21, 27, 33, 52, 53, 56, 69, 73, 86, 90, 93, 98

EXTERNAL FACTORS

2, 3, 5, 6, 7, 8, 17, 18, 21, 22, 24, 25, 27, 28, 29, 30, 31, 33, 36, 38, 39, 40, 46, 47, 50, 56, 59-60, 66, 67,-68, 69, 70, 71, 73, 88-89, 90, 91, 93, 95, 97, 98, 99, 100

APPENDIX E

RIVER TOWBOAT VOYAGE CAUSAL FACTOR CATEGORIES

In this composite list, each casualty causal factor is followed by the block numbers in Figure 4 in which the factor could lead to a collision, ramming, or grounding, based on the collective experience of the committee.

FAILURE TO DO TASK

2, 13, 15, 16, 19, 27, 28, 30, 37

FAILURE TO CORRECTLY PERFORM TASK

1, 2, 3-6, 7, 8, 9, 10, 11, 14, 15, 17, 18, 19 22,
23, 24, 25, 30, 31, 32, 33, 34, 35, 36, 37

LACK OF KNOWLEDGE/TRAINING

2, 3-6, 8, 11, 12, 13, 18, 22, 23, 24, 25, 30, 31,
32, 35, 36

ENVIRONMENTAL FACTORS

10, 11, 14, 15, 19, 26, 29, 30

INCOMPLETE/INCORRECT INFORMATION

1, 3-6, 12, 17, 22, 30

LANGUAGE/LITERACY PROBLEMS

SOCIAL PROBLEMS

30

EQUIPMENT PROBLEMS

7, 9, 10, 11, 14, 15, 18, 19, 22, 23, 24, 26, 28, 30, 34, 37, 38

MANAGEMENT

1, 7, 9, 13 17, 24

EXTERNAL FACTORS

11, 16, 21, 28, 30

APPENDIX F

GREAT LAKES VOYAGE CAUSAL FACTOR CATEGORIES

In this composite list, each casualty causal factor is followed by the block numbers in Figure 5 in which the factor could lead to a collision, ramming, or grounding, based on the collective experience of the committee.

FAILURE TO DO TASK

4, 6-10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 23, 24, 25, 26, 27, 28, 30, 33, 34, 35, 36, 37, 39, 45, 49, 51, 52, 54, 56, 61, 62, 64, 65, 66, 67, 68, 74, 80, 81, 83, 85, 90, 91, 93, 94, 95, 96, 100, 107, 108, 109, 110, 111, 117, 118, 120, 121, 124, 126, 130, 131, 133, 136, 137, 139, 142, 143, 144, 145, 146, 147

FAILURE TO CORRECTLY PERFORM TASK

1, 2, 3, 4, 5, 6-10, 11, 12, 15, 18, 19, 21, 22, 23, 24, 26, 27, 28, 30, 31, 33, 34, 36, 37, 38, 39, 40, 42, 43, 45, 46, 47, 48, 50, 51, 52, 53, 54, 55, 56, 58, 59, 60, 63, 64, 65, 67, 68, 69, 70, 73, 74, 75, 76, 77, 79, 80, 81, 82, 83, 84, 85, 87, 88, 89, 92, 93, 95, 97, 98, 99, 101, 102, 103, 104, 106, 107, 108, 110, 111, 112, 114, 116, 117, 119, 120, 121, 122, 123, 124, 125, 126, 127, 129, 130, 132, 134, 135, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 150, 151, 153, 154, 155

LACK OF KNOWLEDGE/TRAINING

4, 6-10, 11, 21, 30, 31, 32, 34, 39, 41, 42, 43, 44, 45, 49, 52, 55, 56, 57, 58, 59, 60, 65, 68, 70, 71, 72, 73, 74, 78, 81, 84, 85, 86, 87, 88 , 89, 97, 99, 102, 108, 111, 113, 114, 115, 116, 117, 118, 121, 125, 126, 129, 134, 135, 140, 149, 150, 153

ENVIRONMENTAL FACTORS

19, 24, 34, 39, 45, 46, 52, 59, 60, 65, 68, 74, 75, 81, 88, 89, 97, 108, 11, 117, 122, 126, 134, 142, 146, 150, 153

INCOMPLETE/INCORRECT INFORMATION

1, 2, 4, 6-10, 15, 32, 34, 39, 40, 41, 44, 45, 52, 53, 56, 57, 59, 60, 65, 68, 69, 71, 72, 74, 81, 82, 85, 86, 88, 89, 95, 97, 108, 111, 112, 113, 115, 117, 121, 126, 128, 134, 135, 149, 150, 153

LANGUAGE/LITERACY PROBLEMS

SOCIAL PROBLEMS

2, 13

EQUIPMENT PROBLEMS

12, 16, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 31, 33, 34, 35, 36, 38, 39, 40, 42, 43, 45, 47, 49, 51, 52, 53, 54, 56, 58, 59, 60, 61, 62, 64, 65, 66, 67, 68, 69, 70, 73, 74, 76, 78, 80, 81, 82, 83, 85, 88, 89, 90, 91, 93, 94, 95, 96, 97, 98, 100, 101, 102, 103, 104, 106, 107, 108, 109, 110, 111, 112, 114, 116, 117, 118, 120, 121, 123, 124, 126, 127, 129, 130, 133, 134, 135, 136, 137, 139, 141, 14, 143, 144, 145, 146, 148, 150, 151, 153, 154, 155

MANAGEMENT

1, 2, 5, 12, 13, 16, 34, 37, 45, 48, 49, 50, 55, 56, 63, 65, 74, 77, 78, 79, 84, 85, 92 95, 108, 117, 118, 119, 121, 125, 131, 134, 135, 138

EXTERNAL FACTORS

4, 11, 13, 15, 17, 19, 20, 21, 24, 25, 26, 27, 33, 34, 35, 36, 38, 39, 40, 45, 51, 52, 53, 56, 62, 64, 65, 66, 67, 68, 69, 74, 80, 81, 82, 83, 85, 91, 93, 94, 95, 96, 107, 108, 109, 110, 111,112, 117, 121, 126, 127, 130, 133, 137, 139, 141, 142, 143, 146

APPENDIX G

HUMAN FACTORS DATA SOURCES

BOOKS

Chapanis, A. MAN-MACHINE ENGINEERING. Belmont, California, Wadsworth, 1965. Bibliog. (658.5/C46m). Comprehensive treatment of man-machine engineering. Nontechnical format.

Chapanis, A., Garner, W. R., and Morgan, C. T. APPLIED EXPERIMENTAL PSYCHOLOGY: HUMAN FACTORS IN ENGINEERING DESIGN. New York, Wiley, 1949. (658.5/C46). Application of experimental psychology to the design of machines for the use of men.

Chapanis, A. RESEARCH TECHNIQUES IN HUMAN ENGINEERING. Baltimore, Johns Hopkins, 1959. (658.5/C46r). Provides a good overview of various techniques of investigation and analysis that can be used in work on human engineering problems.

Damon, A., Stoudt, H. W., and McFarland, R. A. THE HUMAN BODY IN EQUIPMENT DESIGN. Cambridge, Massachusetts, Harvard University Press, 1966. (658.5/D16). Intended as a guide for the designer of equipment involving human body size and mechanical capabilities. A comprehensive handbook of anthropometric data compiled from military and civilian populations (male and female).

DeGreene, K. B., editor. SYSTEMS PSYCHOLOGY. New York, McGraw-Hill, 1970. A comprehensive discussion of psychology and human factors integrated into the systems approach to design.

Dreyfuss, H. THE MEASURE OF MAN-HUMAN FACTORS IN DESIGN. Second edition, New York, Whitney Library of Design, 1967. (658.5/D77:2). Contains a collection of anthropometric charts and data pertaining to the population.

Dreyfuss, H. DESIGNING FOR PEOPLE. New York, Simon and Schuster, 1955. (745/D77). The industrial design story with an emphasis on the user.

Fitts, P. M., and Posner, M. J. HUMAN PERFORMANCE. Belmont, California, Brooks/Cole, 1967. (152/F54). Emphasizes factors

affecting human performance capabilities, both cognitive and perceptual-motor.

Gagne, R. M., editor. PSYCHOLOGICAL PRINCIPALS IN SYSTEM DEVELOPMENT. New York, Holt, Rinehart, and Winston, 1962. (658.54/G13). Contains a general discussion of the role of the personnel subsystem and human factors in the development of new systems.

Glazer, S., and Hammell, R. "Man-Machine Interaction," Chapter 12 in PHYSICAL DESIGN OF ELECTRONIC SYSTEMS: VOLUME I, DESIGN TECHNOLOGY. Englewood Cliffs, New Jersey, Prentice-Hall, 1970. (E4004/B426p).

Hammell, R. "Human Characteristics," Chapter 11 in PHYSICAL DESIGN OF ELECTRONIC SYSTEMS: VOLUME I, DESIGN TECHNOLOGY. Englewood Cliffs, New Jersey, Prentice-Hall, 1970. (E4004/B426p). Bibliography. Investigates human factors involved in the man-machine interface.

Harris, D. H., and Chaney, F. B. HUMAN FACTORS IN QUALITY ASSURANCE. New York, Wiley, 1969. Intended to provide a source of information and ideas for those concerned with quality objectives in industrial operations and to provide material useful in the education of human factors specialists.

Johnsen, E. G., and Corliss, W. R. HUMAN FACTORS APPLICATIONS IN TELEOPERATOR DESIGN AND OPERATION. New York, Wiley, 1971. (629.89/J65h) "A teleoperator is a general purpose, dexterous, cybernetic machine"--i.e., a robot. Contains a discussion of man-machine interface and of display technology in control problems. Includes a lengthy bibliography.

McCormick, E. J. HUMAN FACTORS ENGINEERING. Third edition, New York, McGraw-Hill, 1970. (658.5/M13:3). Combines a general background discussion with the presentation of various kinds of data appropriate for human factors work. (4th ed. 1976)

Meister, D. HUMAN FACTORS: THEORY AND PRACTICE. New York, Wiley, 1971. New and highly useful treatment of human factors in design work.

Meister, D., and Rabideau, G. F. HUMAN FACTORS EVALUATION IN SYSTEM DEVELOPMENT. New York, Wiley, 1965. (658.5/M51). Mostly concerned with personnel subsystem test and evaluation, but contains other useful information as well.

Morgan, C. T., Cook, J. S., Chapanis, A., and Lund, M. W., editors. HUMAN ENGINEERING GUIDE TO EQUIPMENT DESIGN. New York, McGraw-Hill, 1963. (658.5/M82). Produced by the joint services (Army, Navy, Air Force), this book was intended as a general reference work of human factors data and contains a great number

of charts, graphs, and tables that can be used in equipment design. Now out of print; was updated by Harold VanCott of American Psychological Association, Washington, D.C., in 1972 and published by the Government Printing Office.

Sinaiko, H. W., and Buckley, E. P. "Human Factors in the Design of Systems," Paper 1 in SELECTED PAPERS ON HUMAN FACTORS IN THE DESIGN AND USE OF CONTROL SYSTEMS. Sinaiko, H. W., editor. New York, Dover, 1961. (E17/S61) Contains an extensive bibliography and reading list. The appendix is a human factors checklist for system designers. Also appeared as NRL Report 4996, Naval Research Laboratory, Washington, D.C., 1957.

Singleton, W. T., Fox, J. G., and Whitfield, D., editors. MEASUREMENT OF MAN AT WORK: AN APPRAISAL OF PHYSIOLOGICAL AND PSYCHOLOGICAL CRITERIA IN MAN-MACHINE SYSTEMS. London, Taylor and Francis Ltd., 1970. Based on papers from a symposium sponsored by the International Ergonomics Association, the book is structured on a tripartite scheme: The section on "man" discusses concepts of human function and behavior; the "techniques" section reviews the definition and acquisition of measurements; the third section on "applications" presents several areas of practical interest. Of general interest.

Woodson, W. E., and Conover, D. W. HUMAN ENGINEERING GUIDE FOR EQUIPMENT DESIGNERS. Second edition, Berkeley, University of California Press, 1964. (658.5/W89:2). Presents principles, guidelines, and recommendations for the designing of "well-human-engineered products." A practical, straightforward approach.

Utility of Reference Books

All of the above books contain useful information that can be applied to the design of systems. For information concerning the design of controls and displays, Morgan et al., McCormick, and Woodson and Conover should all provide a considerable amount of useful data. Woodson and Conover's book does not contain as much design data as Morgan or McCormick, but since it is not overly technical and contains many illustrations, it may be a good source to start with.

For the design of workspaces, Dreyfuss is an excellent source of anthropometric data, although such data are also provided in Morgan et al., McCormick, and Woodson and Conover. Morgan also provides procedures on how to go about laying out equipment and workspaces.

For environmental data, the above sources should prove useful. One may also want to consult the IES Lighting Handbook, Illuminating Engineering Society, New York (E2/I29), and the ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating, and Air

Conditioning Engineers, Inc., New York, 1967 (R697/A53a). The best source for test and evaluation methods and procedures is the Meister and Rabideau book. If the data cannot be located in these sources, try looking up additional sources in the Human Factors Engineering Bibliography Series listed below.

Statistical analysis is frequently a necessary component of effective work with human factors data. There are many excellent statistical texts available. The following titles may be useful for the nonspecialist in mathematics and statistics.

Edwards, A. L. EXPERIMENTAL DESIGN IN PSYCHOLOGICAL RESEARCH. New York, Holt, Rinehart and Winston, 1968. (150.7/E26:3). Covers the principles of design and statistical analysis of data. Can be understood by individuals familiar with elementary statistical analysis and having a working knowledge of algebra.

Lewis, D. QUANTITATIVE METHODS IN PSYCHOLOGY. New York, McGraw-Hill, 1960. (150.7/L67). A useful treatment of curve-fitting and correlation techniques. Does not require great mathematical sophistication.

Johnson, N. L., and Leone, F. C. STATISTICS AND EXPERIMENTAL DESIGN IN ENGINEERING AND THE PHYSICAL SCIENCES. 2 Volumes. New York, Wiley, 1964. (519.7/J673). Provides a sound understanding of, and facility with, basic statistical techniques. Volume I makes frequent use of examples and provides a large variety of exercises. Volume II treats models in detail. Includes sample design structures and a selected bibliography of statistical tables.

Siegel, S. NON-PARAMETRIC STATISTICS FOR THE BEHAVIORAL SCIENCES. New York, McGraw-Hill, 1956. (301.01/S57) A comprehensive treatment of a large number of statistical techniques that are simple to understand and apply. These techniques are less powerful than parametric techniques and are used when the assumptions of parametric statistics cannot be met.

Winer, B. J. STATISTICAL PRINCIPLES IN EXPERIMENTAL DESIGN. Third Edition, New York, McGraw-Hill, 1971. (311/W76). A serious treatment of analysis of variance. Computational techniques and formulae are presented in detail, allowing sophisticated use of analysis of variance.

BIBLIOGRAPHIES AND REPORTS

In addition to the books described, there are many reports and bibliographies useful in a given human-factors subject area. The following sources may be useful for design work in a particular subject area.

Design of Displays

Visual Presentation of Information. Baker, C. A., and Grether, W. F., WADC Tech. Rep. 54-160, Wright Patterson AFB, Ohio, August 1950.

Interpretation of Complex Images: Literature Survey. Kause, R. H., Goodyear Aerospace Corp., Akron, Ohio, February 1965. AD 614703.

Legibility of Alphanumeric Characters and Other Symbols. Cornog, D. Y., Rose, F. C., and Walkowicz, J. L., U. S. Dept. of Comm., Natl. Bureau of Standards, Misc. Publ. 262-1, 1964. (655/C81).

Radar Symbology: A Literature Review. Honigfeld, Alfreda R., Tech. Memo 14-64, Proving Ground, Maryland, 1964 (contains data applicable to CRTs). AD 461180.

Trends and Developments in Visual Displays. Crook, M. N., Raben, M. W., and Wade, E. A., Tufts Univ., Human Engineering Information and Analysis Service, Dec. 1967, AD 673091.

Research Requirements for the Human Engineering Design of Visual Displays. Sullivan, D. and Meister, D., Bunker-Ramo Corp., California, December 1969. AD 701790.

Displays for Command and Control Centers. Gabelman, I. J., editor. Advisory Group for Aerospace Research and Development. AGARD Conf. Proc. No. 23. Slough, Eng., Technivision Services, 1969. (Proc. of 11th Tech. Meeting of Avionics Panel, Munich, Nov. 1966). (T9/A24d).

Design of Controls

The Methodology of Control Panel Design. Meister, D., and Farr, D., AMRL Report-TR-66-28, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio, Sept. 1966. AD 646442.

Design of Controls. Ely, J. H., Thomson, R. M., and Orlansky, J., WADC-TR-56-172, Wright Air Development Center, Ohio, Nov. 1956.

Some Principles of the Design of Decision Systems: A Review of Six Years of Research on Command-Control Simulation. Howell, W., Ohio State Univ., Columbus Human Performance Center, Sept. 1967. AD 665469; also AD 684548.

Keyboard Literature Survey Phase I: Bibliography. Remington, R., and Rogers, M., IBM Corp., Systems Development Division, Research Triangle Park, North Carolina, TR29.0042. Jan. 1969. A comprehensive list of literature pertinent to consideration in the design of keyboards.

Workspace Design

Layout of Workspaces. Ely, J. H., Thomson, R. M., And Orlansky, J. WADC-TR-56-171, Aeromedical Laboratory, Wright-Patterson AFB, Ohio, Sept. 1956.

Arrangement of Groups of Men and Machines. Thomson, R. M., Covner, B. J., Jacobs, H. H., and Orlansky, J. ONR ACR-33, Dept. of the Navy, Dec., 1958. PB 151285.

Space Requirements for the Seated Operator. Dempster, W. T. WADC Tech. Rep. 55-195, Wright-Patterson AFB, Ohio, 1955. PB 121053.

Ergonomics in the Design of Office Furniture: A Review of European Literature. Kroemer, K. H. E., and Robinette, J. C. USAF, AMRL, TR 68-80, 1968. AD 848621.

Personnel Subsystems, USAF, AFSC Design Handbook, Series 1-0, General. AFSC DH 1-3, AFSC Headquarters, January 1, 1969.

General

Human Factors Methods for System Design. Folley, J. D., Jr., editor, AIR-290-60-FR-225, American Institute for Research, Pittsburgh, 1960. (658.5/A495)

Guide to Design of Electronic Equipment for Maintainability. Folley, J. D., and Altman, J. W. WADC-TR-56-218, Wright Air Development Center, Ohio, 1956.

An Index of Electronic Equipment Operability. Munger, S. J., Smith, R. W. and Payne, D. AIR-C43-1-62-RP1,2,3. Jan. 31, 1962, American Institute for Research, Pittsburgh, 1960.

Human Resources Research Organization (HumRRO) Bibliography of Publications, as of 30 June, 1969. Sept. 1969. 312 pp. Bibliography reports on behavioral research work at George Washington University Human Resources Research Office. Includes human performance, particularly in organizational settings. Useful in training.

Human Factors Engineering Bibliographic Series. Project Staff, Human Factors Engineering Information Analysis Center, Institute for Psychological Research, Tufts University.

HEL BIB VOL. 1, 1940-1959, AD 639906 (1965), 1,642 pp.
HEL BIB VOL. 2, 1960-1964, AD 649568 (1966), 1,098 pp.
HEL BIB VOL. 3, covers 1965, AD 657590 (1967), 461 pp.
HEL BIB VOL. 4, covers 1966, AD 677368 (1967), 623 pp.

The Tufts University effort, initiated by the Office of Naval Research, was discontinued in 1968; Vol. 4 is the last issue in this series.

Bioastronautics Data Book. Webb, P., editor, Washington, NASA, 1964. NASA-SP-3006. A summary of quantitative and qualitative human data for basic design requirements of the bioastronautical engineer. Useful for physiological and performance requirements in the more unusual environmental conditions.

JOURNALS AND PERIODICALS

In addition to books and reports, many journals and periodicals are at least partially devoted to human factors topics. Those containing information that may be useful in design work are listed.

Annual Review of Psychology. American Psychological Association, Washington, D.C. (150/A61).

Applied Ergonomics. IPC Science and Technology Publications Ltd., in cooperation with the Ergonomics Research Society, Surrey, England. Each issue includes chapters of the Applied Ergonomics Handbook, a useful guide to the nature and use of ergonomics.

Ergonomics. Ergonomics Research Society and International Ergonomics Association. Taylor and Francis, London. Indexed in British Technology Index, Psychological Abstracts.

Human factors. Human Factors Society. Johns Hopkins Press, Baltimore. Indexed in Psychological Abstracts.

IEEE Transactions on Systems, Man, and Cybernetics, continues IEEE Transactions on Man-Machine Systems, formerly IEEE Transactions on Human Factors in Electronics, and IEEE Transactions on Systems Science and Cybernetics. Institute of Electrical and Electronic Engineers, New York. Indexed in Engineering Index, Psychological Abstracts.

Journal of Applied Psychology. American Psychological Association, Washington, D.C. Indexed in Psychological Abstracts.

Journal of Engineering Psychology. Research International, Margate, N.J. Indexed in Psychological Abstracts, Engineering Index.

Journal of Experimental Psychology. American Psychological Association, Washington, D.C. Indexed in Psychological Abstracts.

Occupational Psychology. National Institute of Industrial Psychology, London, England. Indexed in Psychological Abstracts.

Perceptual and Motor Skills. University of Montana, Box 1441, Missoula, Montana. Indexed in Psychological Abstracts.

The following sources abstract or index reports and journals in the subject areas of human factors and human engineering.

Psychological Abstracts. American Psychological Association, Washington, D.C. Each monthly issue has a subject category, "Engineering Psychology," which encompasses human factors and display design. The annual index should be searched under "Engineering Psychology," "Control," and "Display."

Applied Science and Technology Index. H.W. Wilson Co., New York. Human factors material is indexed under the heading "Human Engineering." It may also be useful to check under the headings "Design" and "Information Display Systems."

Business Periodicals Index. H.W. Wilson Co., New York. Indexes some human factors material as it applies to management or office activities under the headings "Human Engineering" and "Human Information Processing."

Engineering Index. Engineering Index, Inc., New York (Engineering Societies Library). Human factors material is indexed and abstracted under the heading "Human Engineering." Other categories which also may be useful are "Systems Engineering," "Visibility and Vision," "Bioengineering," and "Employees."

Ergonomics Abstracts. Ergonomics Information Analysis Centre, Department of Engineering Production, University of Birmingham, England. A quarterly abstract journal that began publication in 1969. It covers international literature on human factors in man-machine system design and in physical environments. Coverage includes technical reports and journals.

U.S. Government Research and Development Reports (USGRDR). Beginning with Vol. 71(6), March 25, 1971, title is Government Reports Announcement (GRA). U.S. Department of Commerce, National Technical Information Service, Washington, D.C. Abstracts and indexes government research reports released through the National Technical Information Service (NTIS), formerly the "Clearinghouse," Springfield, Virginia (CFSTI). Reports are classified under the heading "Human Factors Engineering" and are grouped in the monthly issues of GRA, in Group 5E, 5G, and 5H of Field 5, "Behavioral and Social Sciences." The monthly and annual indexes to the announcements use the headings "Human Engineering Test Methods," "Human Factors Engineering," "Display Devices," and "Human Factors Engineering."

REVIEW ARTICLES ON HUMAN FACTORS:

Kraft, J. "A 1961 Compilation and Brief History of Human Factors Research in Business and Industry." Human Factors, 3(4), December 1961, 253-283.

Ronco, Paul G. "A Bibliography and Overview of Human Factors Reference Works." Human Factors, 5(4), December 1963, 549-568.

Costello, R. G., and Higgins, T. J. "An Inclusive Classified Bibliography Pertaining to Modeling the Human Operator as an Element in an Automatic Control System." IEEE Transactions in Electronics, 7(4), December 1966, 174-181.

Poulton, E. C., "Engineering Psychology." Annual Review of Psychology, 17, 1966, 177-200 (150/A61).

Meister, D., and Farr, D. E., "The Utilization of Human Factors Information by Designers." Human Factors, 9(1), February 1967, 71-87.

Wargo, M. J., "Human Operator Response Speed, Frequency, and Flexibility: A Review and Analysis." Human Factors, June 1967, 9(3), 221-238.

Fucigna, J. T., "The Ergonomics of Offices," Ergonomics, September 1967, 10(5), 589-604.

Human Factors Society Metropolitan Chapter. Symposium Proceedings, "Head-Up Displays." M. Brooks, Symposium Chairman, September 11, 1968.

McCormick, Ernest J., "The Industrial-Engineering/Human Factors Interface." Human Factors, 11(2), April 1969, 107-121.

Shackel, B. "Man-Computer Interaction: The Contribution of the Human Sciences." Ergonomics, 12(4), July 1969, 485-499.

Singleton, W. T., "Display Design: Principles and Procedures." Ergonomics, 12(4), July 1969, 519-531. (Also in IEEE Trans. on Man-Machine Systems, 10(4), 1969.)

Schrenk, L. P., "Aiding the Decision Maker: A Decision Process Model." Ergonomics, 12(4), July 1969, 543-557.

Nickerson, R. S., "Man-Computer Interaction: A Challenge for Human Factors Research." IEEE Trans. on Man-Machine Systems, 10(4), 1969, 164-180.

Miller, R. B., "Archetypes in Man-Computer Problems Solving."

Galitz, W. O., and Laska, T. J., "Computer System Peripherals and the Operator." Computer Design, August 1969, 52-56.

Parsons, S. O., and Lebuch, J. L., "The Standardization of Human Factors Data." Human Factors, 12(1), February 1970, 55-62.

Human Factors, 12(2), April 1970. This is a special issue devoted to "Human Factors in Information Processing Systems."

Human Factors Society Metropolitan Chapter. Symposium Proceedings, "Human Factors Applications in Urban Development." T. K. Sen, Editor and Symposium Chairman, April 11, 1970.

Chapanis, A., "Plenary Discussion: Relevance of Physiological and Psychological Criteria to Man-Machine Systems: The Present State of the Art. Ergonomics, 13(3), May 1970, 337-346.

Human Factors, 12(3), June 1970. Special issue devoted to "Maintenance and Maintainability." Includes Robinson, J. E., Deutsch, W. E., and Rogers, J. G., "The Field Maintenance Interface Between Human Engineering and Maintainability Engineering." 253-260.

Teel, K. S., "Is Human Factors Engineering Worth the Investment?" Human Factors, 13(1), February 1971, 17-21.

Klemmer, E. T., "Keyboard Entry." Applied Ergonomics, 2(1), March 1971, 2-6.

Talbot, J. E., "The Human Side of Data Input." Data Processing Magazine, 13(4), April 1971, 28-35.

APPENDIX H

SELECTED BIBLIOGRAPHY

Works are listed under various headings. Addresses of sources are given at the end of this appendix.

SHIP OPERATION AND CONTROL

PROCEEDINGS, FIFTH SHIP CONTROL SYSTEMS SYMPOSIUM, October 30-November 3, 1978, Annapolis, Maryland. Contains numerous papers on ship and machinery control, looking at automation, system design, hardware, human factors, and training.

PROCEEDINGS, SECOND CAORF SYMPOSIUM, September 28-29, 1978, Kings Point, New York, and PROCEEDINGS, THIRD CAORF SYMPOSIUM, October 15-16, 1979, Kings Point, New York. The second and third CAORF (Computer Aided Operations Research Facility) symposiums presented the simulator research and training programs conducted with the Maritime Administration's bridge simulator at the Merchant Marine Academy, King's Point, New York.

PROCEEDINGS, SHIP OPERATION AUTOMATION, II, August 30-September 2, 1976, Washington, D.C. A collection of papers on automation of all aspects of merchant ship operation, including bridge and machinery room design.

U.S. COAST GUARD REPORTS

Final Report: Analysis of Ramming and Grounding Accidents Not Involving Bridges, Mar. 1976, AD A024546

Analysis of Bridge Collision Incidents, Volume I, Feb. 1976, AD A029034

Analysis of Bridge Collision Incidents, Volume II, July 1976, AD A036732

Vessel Motion Simulation Manual, Mar. 1976, AD B013272

Vessel Maneuvering Simulation, July 1976, AD A029392

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A Preliminary Study of Pilot Decision Making, July 1976, AD A029715

Task Analysis Report Relative to Collisions, Rammings and Groundings Prevention, Dec. 1976, Volume I, AD A037316, Volume II, AD A037317, Volume III, AD A037442

Reliability Study of Functional Job Analysis Task Statements, July 1977, AD A045441

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Simulation of Bridge Collision Incidents Involving Inland Waterway Tows, July 1978, AD A053644

Simulation of Bridge Collision Incidents Involving Inland Waterways Tows: Program Users Documentation, June 1978, AD A058321

The Prediction of River Tow Maneuvering Performance, May 1978

Tanker Structural Analysis for Minor Collisions, Dec. 1975, AD A0031031

NATIONAL MARITIME INSTITUTE PAPERS (British)

No. 3, "The Identification of Maneuvering Equations From Ship Trial Results,", A. D. Gill, Aug. 1976

No. 4, "Evaluation of 1975 Buoyage Land Boundry Marking in the Dover Strait," J. Fairbrother, Nov. 1976

No. 5, "Salient Features of World-Wide Collisions and Strandings During 1975," J. C. Shipway, Nov. 1976

No. 6, "Hydrodynamic Aspects of Shallow Water Collsions", I. W. Dand, Nov. 1976

No. 8, "Ship-Ship Interaction in Shallow Water", I. W. Dand, March 1977

No. 12, "Collisions and Strandings in the Dover Strait Area: 1960-1976", I. Bowoldge, April 1977

No. 15, "The Modeling of Marine Traffic Flow and Collision Risk," G. R. G. Lewsion, June 1977

No. 20, "Analysis of Rogue Traffic Identified in the Dover Strait During 1974-75 With Particular Reference to

Crossing Behaviour," Capt. Emden and R. F. Chalf, Aug. 1977

No. 21, "The Risk of Ship Encounter Leading to a Collision," G. R. G. Lewison, Feb. 1978

No. 27, "Determination of Mariners Reaction Times," R. G. Curtis, Dec. 1977

No. 28, "An Analysis of the Dangers of Ships Overtaking," R. G. Curtis, March 1978

No. 39, "The Risk of Ship/Platform Encounters in U.K. Waters," G. R. G. Lewison, May 1978

MARITIME TRANSPORTATION RESEARCH BOARD REPORTS

CASE STUDIES IN MARITIME INNOVATION, MTRB, May 1978 (NTIS No. AD A053926)

HUMAN ERROR IN MERCHANT MARINE SAFETY, MTRB, June 1976 (NTIS No. AD A028371)

TOWARD AN IMPROVED U.S. MERCHANT MARINE: A RECOMMENDED PROGRAM OF STUDIES, MTRB, January 1976 (NTIS No. AD A021103)

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MERCHANT MARINE CASUALTY DATA, MTRB, July 1973 (NTIS No. AD 766491)

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Maritime Transportation Research Board
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APPENDIX I

FLIGHT SAFETY FOUNDATION BULLETINS

FLIGHT SAFETY FOUNDATION, INC.
5510 Columbia Pike, Arlington, VA 22204 USA
(703) 820-2777

ACCIDENT PREVENTION BULLETIN

June 1980

1. TAKES TWO TO TANGO

. . . and frequently more than two. As one captain stated it, "The *name of the game* is 'crew concept.' The old one-man-band idea is not for modern jet airlines. It takes the full crew, each knowing his job and performing his duties precisely and unfailingly to provide the margins needed for unexpected emergencies or malfunctions."

Not too long ago an airline twin-jet came in too high and too fast, overran the departure end of the runway, continued down a slope until it hit a drainage ditch, sheared off its landing gear and then slid another 100 yards beyond the drainage ditch. Luckily, only one passenger was injured, but the airplane was substantially damaged. In answering "whys" of this accident, the NTSB referred to the first officer's failure to make any of the required altitude, descent rate, or airspeed callouts during the approach. This lapse in teamwork or crew coordination added to the captain's workload during the critical phase of flight.

British Airways summed up situations like this by saying in a recent issue of its "Air Safety Review", "Many air crashes could have been prevented simply by an alert copilot speaking up. So, if you are a copilot, never sell your job short . . . Aircraft commanders depend on you . . ."

Call it crew concept, crew coordination or teamwork, it's all the same. It's working together for safety — yours and your passengers.

(Index: *Flight Operations*)

2. APU PROBLEM

One of the overseas airlines recently added a caution concerning a possible fuel leakage in the unpressurized tail area after false APU starts. As this airline stated it,

"A few cases have been reported of fuel leakage in the tail compartment after false APU starts. In one case this even led to the development of smoke from the area after a subsequent successful APU start. After shutdown, an inspection revealed evidence of a fire, i.e., scorched paint, a slightly buckled skin and burnt wires in the area below the APU exhaust duct on the right-hand side of the DC-9 tail compartment.

"Also, residual debris found in the area probably blocked the drain overboard hole. As no evidence of fuel line leakage could be found, it is assumed that after a false start, fuel may have seeped into the tail compartment via the expansion joint in the APU exhaust duct. As a result, the FAA issued an Airworthiness Directive requiring a regular inspection of the fuel drainage hole for blockage. Furthermore, it prohibited trying an APU re-start after an unsuccessful attempt until it has been ascertained that there is not fuel leakage from the overboard drain.

"The fuel leakage problem will be solved by installing a baffle in the exhaust expansion joint. This modification is expected to be completed by January 1981. In the meantime, there may be some operational consequences, e.g., when operating a charter into an airport where an A-check is done by pilots.

"If an unsuccessful APU start occurs, one of the pilots must check the overboard drain. It is located, when facing the right aft fuselage, just forward of the top right-hand corner of the APU access panel in an unpainted area within a row of rivets. If a fuel leakage is observed from the overboard drain, then the tail compartment forward of the APU exhause duct must be cleaned and dried, BUT . . this cannot be accomplished without technical assistance.

(Index: *Detection*)

3. 'NONYMOUS REPORTS - BIG 'N LITTLE

With the advent of sunny days and mild temperatures, more and more a/c are flying the skyways, many of the "small ones" having to be mixed in with the larger and heavier airline types. Hopefully, there will be answers to many of the "mixture" problems, making the aerial highway safer for everyone, big 'n little.

From a turbojet pilot:

"It seems to me the overall quality of our terminal area air traffic control system is slipping a bit. In the past eight weeks of air carrier flying, I have been required to deviate from a 'standard' runway approach profile no less than four times due to a poorly controlled/coordinated light aircraft getting in the way. In comparison, I have a total of two such experiences in the past 10 years of flying.

"In three of the four cases mentioned above, the light aircraft was on an approach control or tower frequency other than the one we were on and was allowed to interfere with the flow of the heavier turbine-powered landing traffic. Only after we asked questions about the 'unknown' traffic was remedial action taken by the controlling agency on the ground.

"To the best of my knowledge, no FAR's were violated, and there were no near-misses. But pilot distraction and passengers discomfort (abrupt maneuvers on final approach) would not have been necessary if somebody on the ground had not gotten sloppy.

"If our terminal air control operations are not tightened up, it will be only a short time before another mid-air similar to San Diego happens.

"Before someone screams that I am anti-general aviation, let me add that I also fly small aircraft, occasionally in congested terminal areas, and I make damn sure that my flight pattern is fully coordinated with those of the 'big boys'.

"I urge terminal area traffic controllers, busy as they are, to make a stronger continuous effort to ensure the safe coordination of local air traffic of all types and sizes. I recommend that the FAA impose much stiffer penalties on those individual pilots who will not coordinate their flight patterns in terminal areas. Needless to say, all of us had better keep our eyes open and not fall into the delusions that all of the local traffic seen outside the cockpit is properly and safely coordinated. It ain't necessarily so!"

Amen . . . soit . . . or in any language it's affirmative, a word of affirmation. Your suggested coordination of flight patterns would seem to be another way of saying, keep the "little" ones under control which supposedly in the US under FAR 91 they are. Referring to AIM, (Airman's Information Manual) Part 165 a: *"Regardless of weather conditions, ATC authorization is required prior to operating within a TCA (Terminal Control Area). Pilots should not request such authorization unless the requirements of FAR 91.24 and FAR 91.90 are met (meaning two-way radio, a VOR TACAN receiver, a private pilot certificate or better, or at an IAS of not more than 200 kts."*

Answer to "Roughrider" (March APB) from an L-1011 man in Bahrain:

"Roughrider departures in your March 1980 bulletin has some very good points. We operate L-1011s into a major airport in the Indian sub-continent. Taking-off on the Westerly runway can be an eyeball bouncing, spine-shattering, teeth-jerking experience for the crew, just think what it does to the aircraft, especially as the big bumps come at the intersection with the NW/SE runway at around 130 kts.

"The usual takeoff technique in the L-1011 is to set 10° flap prior to setting out down the bumpy road to fly.

"Several company pilots and flight engineers, having had enough 'vibration therapy', approached the Fleet Captain and suggested that perhaps the use of 22° flap could make it easier on the machine if not the man.

"We now use this technique with a slightly altered minimum takeoff power setting and we find that we miss most of the heavy knocks. Consideration is now being given to using the same technique at another 'Roughrider' airport up near the Pyramids."

Thanks to this real pro whose suggestion may smooth out many a takeoff down a really rough runway. Come on, guys, keep the words of wisdom coming. We all need 'em!!

(Index: *Flight Operations*)

FLIGHT SAFETY FOUNDATION, INC

ANONYMOUS REPORT

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains an evaluation of the research needed to prevent marine casualties--specifically collisions, rammings, and groundings--associated with vessel controllability. A review of existing studies and casualty data, combined with the committee's experience, resulted in the identification of four major categories of marine-casualty factors: personnel; ports and waterways; aids to navigation; and vessel characteristics, maneuverability, and hydrodynamics. A significant amount of research on systems, hardware, and human behavior exists that is

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20. Abstract (continued)--

applicable to these categories. However, there are important gaps in basic hydrodynamic research. The commitee further determined that a basic problem in the maritime industry is not so much the lack of research, but a need to disseminate information, coupled with coordination of research and a serious effort to apply existing knowledge.

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